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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

CARBURETERS
ELECTRIC IGNITION DEVICES
AUTOMOBILE AND MARINE ENGINE AUXILIARIES
POWER-GAS PRODUCERS
MANAGEMENT OF AUTOMOBILE ENGINES
MANAGEMENT OF MARINE GAS ENGINES
MANAGEMENT OF STATIONARY GAS ENGINES
TROUBLES AND REMEDIES
POWER DETERMINATIONS

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the details.

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indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one select the proper formula, method, or process and in teaching him how and when it should be used.

In the first two sections of this volume are described carbureters and electric-ignition devices used in automobile, marine, and stationary gas engines. In the third section are described transmission gears, differentials, clutches, reversing gears, etc. Under power-gas producers are treated the construction and operation of generators and of the purifying devices used in connection with producer plants, as well as cleaning devices employed with blast-furnace gas. In the next three sections are treated the management of automobile, marine, and stationary gas engines, including their installation, starting, stopping, and care. Under the head of troubles and remedies are considered the various troubles encountered in the operation of gas engines, together with their causes and remedies. In the section on power determinations are taken up the methods of determining the power of an engine by means of the indicator, the brake, or by approximate formulas. The entire volume is exceedingly practical and valuable to all interested in gas engines.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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NOTE.—All items in this index refer first to the section and then to the page of the section. Thus, "Ammeter, §18, p11" means that ammeter will be found on page 11 of section 18.

D

CARBURETERS

GASEOUS MIXTURES FOR GAS ENGINES

PROPORTIONS OF MIXTURES

EXPLOSION OF GASES

1. An **explosion** is an extremely rapid combustion accompanied by the formation of gases and increased pressure. A mixture of two or more substances whose chemical combination will cause an explosion is called an **explosive** or an **explosive mixture.** There are also many chemical compounds that will decompose into gases and vapors, the decomposition producing an explosion. These are also termed explosives. When the substance exploding is confined in an unyielding receptacle, there is little or no noise; but when the rise of pressure is transmitted to the surrounding air, as when the explosive is wholly or partially *unconfined*, the explosion is accompanied by a rapid expansion and usually by a loud noise, or report. If the entire mass of the mixture explodes instantly, it is said to **detonate,** and the explosion is called a **detonation.** All detonating compounds can be exploded by percussion, that is, by a blow or jar. The best known example of the ordinary explosive is gunpowder. Nitroglycerin and the substances derived from it, dynamite and giant powder, are examples of detonating compounds.

When a combustible gas or vapor and air are mixed in proper proportions and ignited, the combination of the gas with the oxygen of the air is so rapid as to produce an explosion. The sudden rise of pressure produced is made available for driving a gas engine.

2. Gases available for engine purposes vary so much in their behavior when ignited in the gas-engine cylinder that a knowledge of their performance is of great value to the operator. Certain effects are produced when an explosive mixture is confined in a closed vessel without the opportunity of expansion such as it has in the gas engine. These effects relate to inflammation of the gas, duration of maximum pressure, and rate of fall of pressure. The relation of these to the proportion of gas and air in the cylinder of a gas engine is very important.

3. Ignition.—The operation of setting fire to the gaseous mixture in the engine cylinder by means of a device called an **igniter** is called **ignition.** The moment ignition begins is called the **time of ignition.** The quantity of the mixture of gas and air taken into the cylinder at one time is called the **charge,** and when all of it is ignited, it is said to be **wholly inflamed.** The time elapsing between the time of ignition and the moment when the gas is wholly inflamed is known as the **duration of inflammation** or **duration of the explosion.** The velocity with which the flame is generated in the charge is called the **rate of flame propagation.**

4. Pressure Changes.—When the burning mixture has reached its maximum pressure, a short time may elapse before the pressure begins to fall to that of the atmosphere. This time is the **duration of maximum pressure.** The time elapsing between the moment when the pressure commences its fall from the maximum pressure and the moment when the pressure reaches that of the atmosphere is the **duration of fall of pressure.** The velocity with which this fall of pressure takes place is the **rate of fall of pressure.**

5. Apparatus for Measuring Pressure Changes.—An apparatus for measuring the changes of pressure in explosive mixtures when ignited is shown in Fig. 1. It consists of the explosion chamber *a*, similar to a gas-engine cylinder. The interior of the chamber is connected by means of the passage *b* to the cylinder *c* of an indicator. The pressure in *a*, acting on the piston *d* of the indicator, compresses the spring *e* and

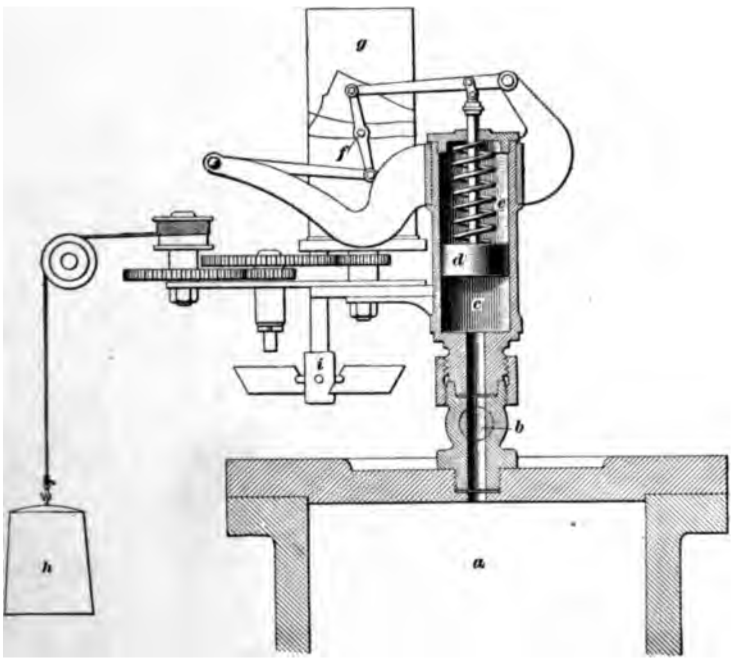


FIG. 1

moves a pencil *f* bearing against the drum *g*. The drum is rotated by means of the clockwork shown. Motion is given to the clockwork by the weight *h*, and the speed of the drum is controlled by the fan governor *i*. The clockwork rotates the drum at a constant speed, so that vertical lines drawn on the surface of the drum at equal distances apart will divide it horizontally into equal spaces indicating equal intervals of time.

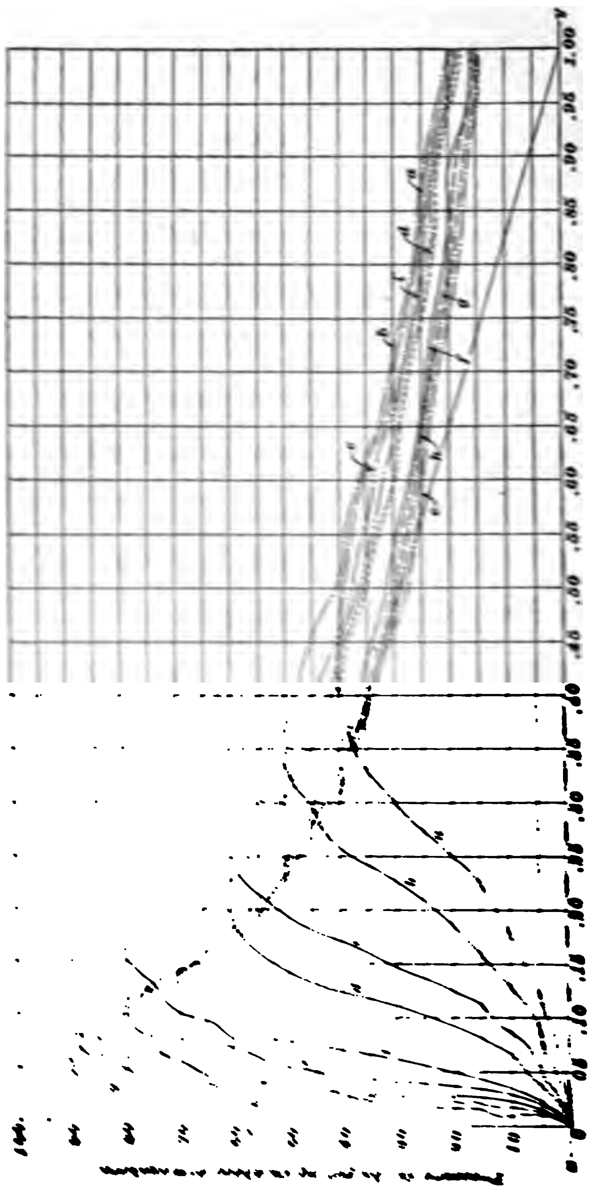


FIG. 2

6. The method of using this apparatus is to fill the chamber *a* with a mixture of gas and air in known proportions, and to ignite the mixture by means of an electric spark. The drum having previously been provided with a removable card and set in motion, the pressure generated by the explosion compresses the indicator spring, raising the pencil, which draws a line on the card. If the card were now removed and laid out flat, the diagram would be similar to one of those shown in Fig. 2, which is a collection of diagrams, made with different proportions of illuminating gas and air, all the gas used being of the same kind. The vertical distances represent pressures in pounds per square inch above atmosphere, and the horizontal distances represent parts of a second. The explosion chamber used in these experiments was 7 inches in diameter by 8½ inches high, or a trifle less than ⅕ of a cubic foot in volume.

7. Pressure Diagrams.—There are nine diagrams in Fig. 2, each one showing the various pressures, during different parts of 1 second, for the explosion and other performances of the different mixtures. Each diagram is indicated throughout by a line of different construction than the others, and is marked by a letter of the alphabet. The mixtures corresponding to each diagram are as follows:

Diagram	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Volumes of Air to 1 Volume of Gas	14	13	12	11	9	7	6	5	4

All diagrams begin at the lower left-hand corner, this being the point indicating the time of ignition. From this point, the pressure rises more or less rapidly to the point of maximum pressure, remains there for a short time, and then falls slowly as the cylinder walls absorb the heat generated by combustion.

8. The mixture *a* reaches its maximum pressure of 40 pounds per square inch in .39 second after the time of ignition, when the pressure remains at a maximum for .08 second, and

then falls gradually to atmospheric pressure. At the expiration of 1 second, the pressure within the explosion chamber is 19.5 pounds per square inch.

The mixture *c* reaches its maximum pressure of 60 pounds per square inch in .24 second, the pressure remains at a maximum for .025 second, and at the end of 1 second it has fallen to 19 pounds per square inch.

The mixtures *f*, *g*, and *h* give nearly the same maximum pressures, namely, 87 pounds, 90 pounds, and 91 pounds, respectively. The duration of the explosion is .065 second for *f*, .045 second for *g*, and .055 second for *h*. The wavy condition of the summits of the lines is due to the vibration of the indicator spring. All three of these diagrams slope downwards immediately after the maximum pressure is reached. The fall of pressure is very slow at first, and the rapid drop does not begin for several hundredths of a second. For practical purposes, the maximum pressures may be said to last about .04 second for *g* and *h*, and .02 second for *f*. Diagrams *g* and *h* after they cross the .2-second line continue practically as one line until they cross the 1-second line at a point indicating a pressure of 15 pounds per square inch. Diagram *f* crosses this line at the 16-pound mark, or just 1 pound above the point crossed by *g* and *h*. Diagram *i* shows the peculiar behavior of a mixture containing one part of gas to four parts of air. There is a gradual rise of pressure for .08 second to 60 pounds per square inch, and from this point the pressure increases by a series of jumps until it reaches 80 pounds per square inch, .16 second after the time of ignition. This "jumping" is an effect invariably produced when the amount of air in the mixture is considerably less than that required for the complete combustion of the gas.

It should be noted that in all these experiments the gases are at atmospheric pressure before ignition. If they were compressed to a higher pressure before ignition, the rate of flame propagation would be much more rapid.

9. Rate of Fall of Pressure.—The rate of fall of pressure is shown by the diagrams to be very nearly the same for

all mixtures. This can be realized most readily by noting that all the diagrams are nearly parallel after the lapse of .5 second. The rate of fall varies from point to point, the pressure falling more slowly toward the latter part of the diagram. If the rate of fall were uniform, this portion of the diagram would appear as a straight line. Suppose, for example, that the fall of pressure of diagram *h* was uniform after a lapse of .4 second. Diagram *h* crosses the .4 line at a pressure of 35 pounds, and the 1-second line at a pressure of 15 pounds; the fall of pressure for .6 second would then be $35 - 15 = 20$ pounds, or $20 \div 60 = \frac{1}{3}$ pound for each .01 second. Then, at the .5 line the pressure should be $35 - \frac{1}{3}(50 - 40) = 35 - 3\frac{1}{3} = 31\frac{2}{3}$ pounds.

In the same manner, it is found that the pressure at the .6-second, .7-second, .8-second, and .9-second lines should be $28\frac{1}{3}$ pounds, 25 pounds, $21\frac{2}{3}$ pounds, and $18\frac{1}{3}$ pounds, respectively. If a straight line is drawn through the points where the .4-second line and the 35-pound line cross, and the 1-second line and the 15-pound line cross, it will be found that the line passes through the five points just mentioned, but that the line of the diagram lies below the straight line. A number of short straight lines can be drawn that will coincide with the diagram. One of these short straight lines will show the rate at which the pressure is falling at that part of the curve, by continuing it until the amount of its slope can be easily determined. A better way is to draw a straight line just touching the curve at the point where the rate of fall is to be determined. A line that just touches a curve and does not pass through it is a *tangent*.

If it is desired to find the rate of fall at the point .45, draw a tangent xy to curve at this point, and find that it crosses the 0-second line at a point indicating a pressure of 57 pounds per square inch, and the 1-second line at the point of 0 pressure; hence the rate of fall at point .45 is $57 - 0 = 57$ pounds per second. After diagram *e* passes the .8 line it will be seen to be practically a straight line; and if it is continued backwards as a straight line, it will cross the 0-second line at a point indicating about 32 pounds pressure. The

rate of fall is then 32 − 15 = 17 pounds per second. If this rate is the same until the pressure falls to 0 pounds, the pressure will be equal to zero in 15 ÷ 17 = .882 second after passing the 1-second line, or in 1 + .882 = 1.882 seconds after the time of ignition.

In the same manner, the rates of fall and the time of reaching zero pressure for any diagram of this nature may be found.

10. Proportion of Gas and Air.—The best proportion of gas and air to use for any gas, in an engine having no compression, is not usually that which has the greatest explosive

TABLE I

PROPORTIONS OF MIXTURES AND RESULTING PRESSURES

1	2	3	4	5	6	7	8
Volumes of Air to 1 Volume of Gas	Proportion of Gas in Mixture	Maximum Pressure per Square Inch	Area of Piston to Each Cubic Inch of Gas	Total Maximum Pressure per Cubic Inch of Gas	Pressure per Square Inch .2 Second After Maximum	Pressure Total to Each Cubic Inch of Gas, .2 Second After Maximum	Mean Pressure on Piston During the First .2 Second
14	$\frac{1}{15}$	40	15	600	31	465	532
13	$\frac{1}{14}$	51.5	14	721	40	560	640
12	$\frac{1}{13}$	60	13	780	42	546	663
11	$\frac{1}{12}$	61	12	732	44	528	630
9	$\frac{1}{10}$	78	10	780	44	440	610
7	$\frac{1}{8}$	87	8	696	47	376	536
6	$\frac{1}{7}$	90	7	630	52	364	497
5	$\frac{1}{6}$	91	6	546	50	300	423
4	$\frac{1}{5}$	80	5	400	46	230	315

power. The best proportion is that which gives the highest pressure for the quantity of gas used. For the purpose of illustration, consider the distance between the end of the cyl-

inder and the end of the piston to be exactly 1 inch; then, for each cubic inch contained in this space, there will be 1 square inch on the surface of the piston. The mixture that will give the highest pressure for the same quantity of gas can be calculated as follows: For instance, take the mixture containing one volume of gas to five volumes of air. In Table I, in which the results of the foregoing experiments are tabulated, the maximum pressure for this mixture is given as 91 pounds per square inch. Since there are five volumes of air and one volume of gas, for each cubic inch of gas there will be six volumes of the mixture and to each cubic inch of gas, in a layer 1 inch deep, there will be 6 square inches of the mixture. Hence the pressure of 91 pounds per square inch is exerted on 6 square inches, and the total pressure exerted by each cubic inch of gas is $91 \times 6 = 546$ pounds.

The mixtures giving the highest pressure for 1 cubic inch of gas are seen to be those having one volume of gas to twelve of air, and one volume of gas to nine of air.

11. The mixture giving the best mean pressure for the first .2 second is that giving 663 pounds to each cubic inch of gas, or the mixture containing one volume of gas to twelve volumes of air. If the power stroke could be considered as taking place without increasing the volume of the space occupied by the gaseous mixture, the pressure remaining at the end of .2 second after the maximum pressure has been reached would be that given in column 7, and the mean or average pressure at the end of .2 second after explosion would be that given in column 8. Column 8 gives a means of comparison of the power to be obtained in using the mixtures indicated in column 1. Thus, the mixture having one volume of gas to thirteen of air is more than twice as powerful as that having one volume of gas to four volumes of air, or in the ratio of 640 to 315, considering the power available during the first .2 second after explosion. Of course, there is no such thing as an engine running without increasing the volume of the cylinder contents, but this assumption is made in order to give a method of comparing the various

mixtures. The gas in each case must also be considered as being so exploded as to have the time of maximum pressure always at the beginning of the stroke.

12. Rate of Flame Propagation.—The **velocity** or **rate of flame propagation** is shown approximately in Fig. 2 by the time elapsing between the time of ignition and the maximum pressure. The rate of flame propagation is approximately the velocity with which the pressure rises after ignition. There have, however, been a number of independent experiments made with apparatus designed expressly for the purpose. In this apparatus, the mixture was confined in a tube from which the gas escaped at a velocity that could easily be measured. The escaping gas was then ignited, and the pressure gradually reduced until the flame rushed back into the tube. The velocity of the escaping gas was then just equal to the velocity of flame propagation in the mixture. This property of explosive mixtures becomes less and less important as the pressure in the gas engine, before ignition, increases, because the higher the pressure at the time of ignition the more rapid is the rate of flame propagation.

GAS AND AIR MIXING

13. Mixing Chamber.—The usual way of creating a combustible mixture of gas and air for use in a gas engine is to introduce the gas into a mixing chamber through which the air is drawn immediately before it enters the cylinder. The gas enters the mixing chamber through a small poppet valve that is opened mechanically by a cam or similar device, at the proper time, the area of the opening of the gas valve being in proportion to the quantity of gas to be supplied. The mixing chamber is usually a part of the gas engine, and is attached to the cylinder as shown in Fig. 3. The gas passes through the valve *a* into the mixing chamber *b*, while air enters at *c*. At *d* is shown the inlet valve to the cylinder *e*, and at *f* the exhaust valve. The inlet valve *d* is a poppet valve, opened by the pressure in the

mixing chamber when the pressure in the cylinder is reduced by movement of the piston *g* on the suction stroke. The exhaust valve *f* is opened mechanically through a cam and rod rotating on the lever *h*. The gas valve *a* is also opened

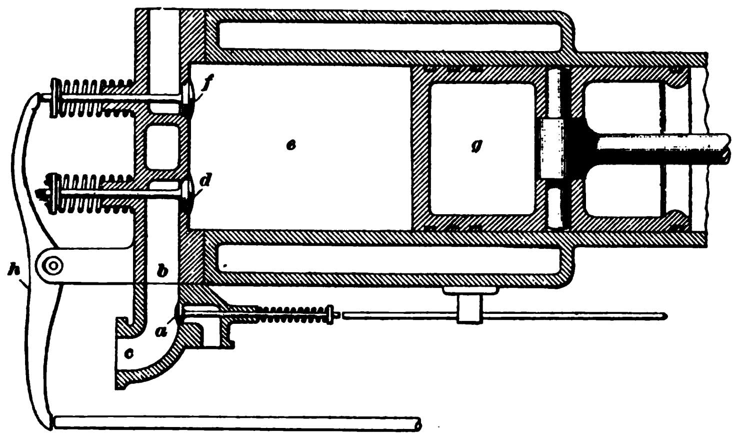


FIG. 3

mechanically and closed by a spring, thus admitting a more definite quantity of gas to the mixing chamber than a poppet valve controlled only by a spring.

14. Regulating Flow of Gas.—It is necessary to operate the gas valve *a* mechanically, for the reason that the gas is under a certain degree of pressure, and if the valve were opened by suction the exact amount of gas going through would be somewhat uncertain. On the other hand, the fact that the gas pressure is likely to fluctuate renders it necessary to control the flow of gas to the gas valve by a regulating valve that may be adjusted by hand. This regulating valve is shown at *a*, Fig. 4. It is provided with an index and notches showing exactly how far it is opened. When an engine is run on illuminating gas, it is generally necessary to reduce the opening of the regulating valve slightly at certain hours and increase it a little at others, owing to fluctuation in the pressure of the gas in the

street mains. The gas as it comes from the main and supply pipe passes first through the meter *b*, then through the shut-off valve *c*, gas bag *d*, and the regulating valve *a*.

The **gas bag,** which is simply a strong rubber bag with connecting tubes at both ends, is employed with all gas engines using gas under pressure, to equalize the flow of

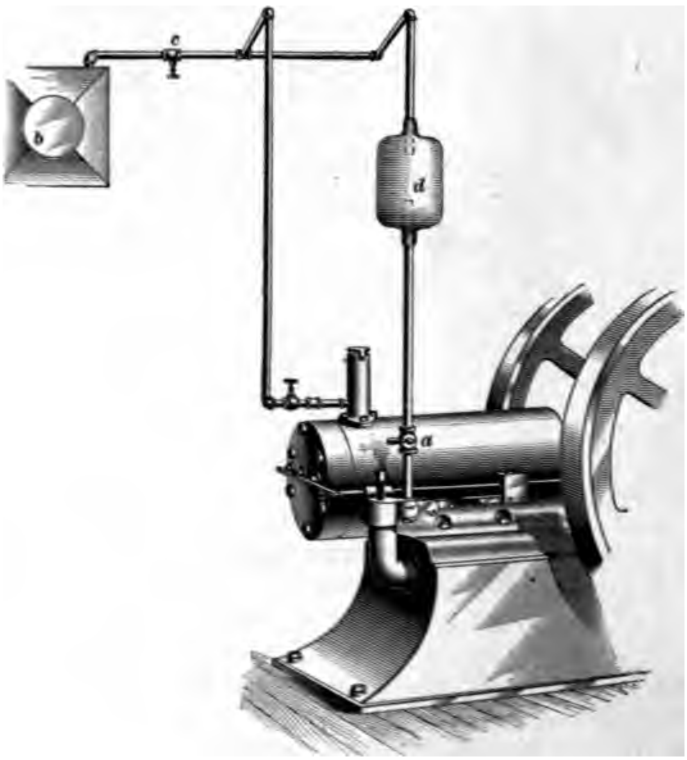


FIG. 4

the gas. Between suction strokes this bag expands owing to the pressure of the gas, and when the suction stroke occurs the gas is taken quickly into the engine, partially collapsing the bag, and consequently reducing the pressure within it to about that of the atmosphere. By the use of this device, the gas pressure at the inlet valve is kept

approximately constant between the beginning ana end of the suction stroke, without the use of specially large piping to carry the gas, as would otherwise be required.

15. The fact that the gas is under pressure, while the air to be mixed with the gas is not, also has an influence on the operation of the gas engine. If the engine runs very slowly, the gas will enter the mixing chamber continuously under its own pressure while the gas valve is open, regardless of the speed of the engine, while the air is drawn through only in response to the suction of the piston. Consequently, a larger proportion of gas will be taken in at slow than at high speeds of the engine. In order to prevent this and maintain an equal mixture at all speeds, the gas-regulating valve must be adjusted by hand to suit changes of speed. As engines of this sort are mostly used in stationary work and run at a constant speed, this feature is not very important, except when the engine is started, at which time it may be troublesome, since a mixture of gas and air in which the proportion of gas is too great will not ignite. The operator must learn by experience the exact position at which the gas-regulating valve should be set, when the engine is turned over slowly, to produce the right mixture for the first explosion. Most of the trouble of inexperienced men in starting gas engines arises from their lack of care and judgment in managing the regulating valve.

16. Mixing Valve.—Another mixing device used in connection with a mechanically opened inlet valve for regulating the proportions of gas and air consists of a suction valve arranged to close simultaneously an air inlet and a gas inlet. It opens of course more or less according to the intensity of the suction, and it is made as light as possible so as not to require any greater amount of suction than is necessary to open it. This kind of **mixing valve,** as it is called, is used only when the engine is regulated by means of a governor, which controls a throttle valve located between the mixing valve and the mechanically opened inlet valve.

An arrangement of this sort is shown in Fig. 5, in which *a* is the combustion chamber; *b*, the exhaust valve; *c*, the mechanically opened inlet valve; *d*, the throttle valve; *e*, the air intake; *f*, the gas intake; *g*, the suction-lifted mixing valve that opens both the air and the gas passages at the same time; and *h*, the water-jacket. In this device,

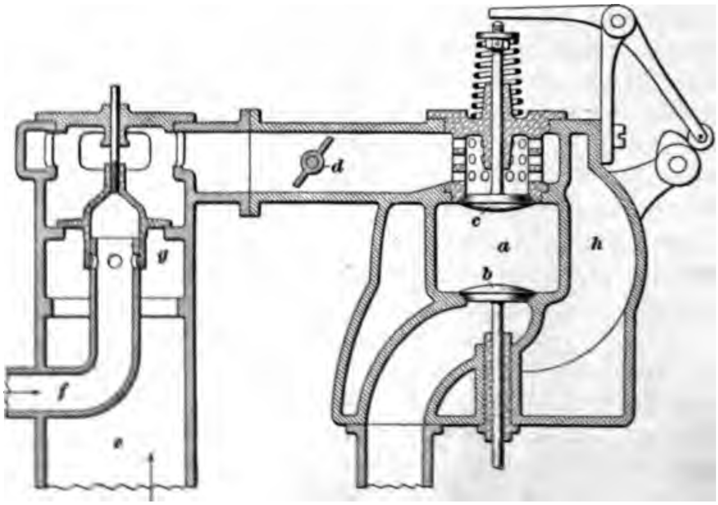


FIG. 5

the governor rotates the throttle valve *d* as the speed rises; and when the speed becomes excessive the passage is closed enough to reduce the charge taken into the cylinder to the required amount.

Besides these simple devices for producing a uniform mixture of gas and air, there is a large number of special devices for special fuels and special types of engines, the most important of which will be considered later.

CARBURIZATION

17. The fuel for a gas engine is a gaseous mixture of hydrogen, carbon, and air. It is produced by mixing some form of hydrocarbon with air. The hydrocarbon is

a substance containing hydrogen and carbon in such a form as to burn readily with the proper mixture of air. Gas engines located so that they can be supplied with natural or artificial gas will usually receive such fuel; but when not so situated, they will be supplied with fuel in the form of carburized air. The most convenient form of hydrocarbon for this purpose is the liquid form, such as gasoline, alcohol, and kerosene. These liquids can be readily transported in tanks and they are obtained directly as a product of nature, needing only to be distilled, refined, or purified.

The evaporation or vaporization of these liquids and the mixing of the vapor with air is called **carburization.**

TYPES OF CARBURETERS

PRINCIPLES OF THE CARBURETER

18. Classification of Carbureters.—A **carbureter** is an appliance for vaporizing liquid hydrocarbons by passing air either over the surface of or through the mass of the liquid or by atomizing the liquid and mixing it with air. The air thus becomes saturated with the vapors of the hydrocarbon. This mixture invariably contains too large a proportion of vapor for an explosive mixture; therefore, before the mixture can be exploded in the engine cylinder it requires the further addition of air.

Carbureters may be divided into three classes, as follows:

1. Those which use a large surface of the hydrocarbon, generally spread out in thin layers, and over which air is compelled to pass. These, for the sake of convenience, will be called **surface carbureters.**

2. Those in which the liquid fuel is placed in any convenient reservoir, usually of great depth, in proportion to the horizontal dimensions, and the air is compelled to pass through the body of the liquid. These may be called **filtering carbureters.**

3. Those which vaporize or atomize the hydrocarbon and

inject it into a current of air. These may be called **spray carbureters**, or **vaporizers.**

The first two types preceded the third in point of time, but the spray carbureters are now used almost entirely.

19. Spray Carbureters.—A good example of a spray carbureter or vaporizer is shown in Fig. 6. It is used in connection with stationary gasoline engines, and gives very satisfactory results. The fuel is drawn to the engine

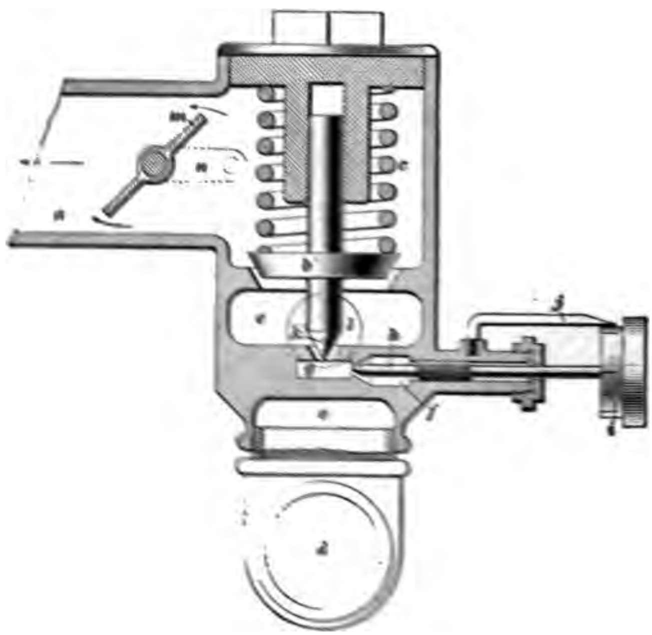


FIG. 6

[illegible] passage a by the suction of the engine. The [illegible] pressure of the spring c during [illegible] and the spring closes the [illegible] The air enters a chamber [illegible] over the top of the [illegible] and downwards through the [illegible] The gasoline is fed

to the vaporizer from a tank placed above the level of the engine; flows first to a reservoir that regulates the flow to the vaporizer by the head due to a constant level maintained by an overflow. From the reservoir, the gasoline flows to the compartment *f*, from which it is admitted to the chamber *g* by the needle valve *h*. The distance the needle valve is opened is indicated on the graduated circle *i* by the stationary pointer *j*. From the chamber *g*, the gasoline is admitted to the mixing chamber *e* by opening the valve *k*, which is rigidly attached to the inlet valve *b*. The mixing chamber entirely surrounds the chamber *g*, so that, when the suction of the engine lifts the valve *b* and thus opens the valve *k*, the gasoline rises through the opening and spreads over a considerable surface. The heated air in the mixing chamber vaporizes the gasoline, and the carburized air rushes through the valve *b* and the passage *a* to the engine.

When it is desired to use gas with this device, the gas-supply pipe is connected to the carbureter at *l*, so that the gas and air mix in the chamber *e* and the mixture is drawn into the engine through the passage *a* as the suction lifts the valve *b*, precisely as with gasoline. In either case, the charge passes from the inlet valve in the direction of the arrows past the throttle, or butterfly, valve *m*, which is operated by the short crank *n* outside the pipe. A rod from the governor is attached to the crank *n*, so that, as the speed of the engine increases, the valve is gradually closed; and, as the speed decreases, the valve is opened, thus regulating the fuel supply.

20. Objections to Surface and Filtering Carbureters.—In the early days of the gasoline engine, the fuel was vaporized simply by having the air drawn over it, or in some cases drawn through it in the form of bubbles by the suction of the piston. Sometimes, to give an increased surface for evaporation, a spiral coil of flannel or other suitable material, as wicking, was arranged so that it would stand partly out of the gasoline, and the air would be drawn over

the surface of the gasoline and the wicking. All devices of this sort have gone out of general use, on account of several important objections. Plain surface evaporation requires a very large surface, in order to evaporate the gasoline fast enough to supply an engine large enough for average demands for power. Again, gasoline is not a homogeneous compound; it is a mixture of light and heavy products of petroleum. When it is evaporated from the surface, the lighter constituents are evaporated first, and hence in time the carbureter contains only the denser portion or *stale gasoline*, as it is called, which will not evaporate with sufficient rapidity to supply the air with the amount of hydrocarbon necessary for explosion. Another objection to carbureters of this sort is that the rate of evaporation of gasoline will depend very largely on its temperature and it is difficult to supply the heat necessary to maintain the required temperature. The gasoline is cooled by its own evaporation, and the heat to make up for this must be supplied in some way, usually by warming the air before it goes into the carbureter by drawing it through a jacket around the exhaust pipe of the engine. Sometimes the gasoline is warmed by means of a jacket around the carbureter, through which is circulated water from the jacket of the engine. If the engine speed is at all variable, the supply of heat varies. It follows that the gasoline, or the air that evaporates it, receives more heat at some times than at others, and the richness of the mixture fluctuates accordingly.

21. Advantage of Spray Carbureters.—For the reasons just stated, the surface and the filtering carbureters for internal-combustion engines have been abandoned, and their place taken by a large variety of forms of spraying devices. In these, the gasoline is given to the air in the form of a jet, or spray, that is drawn from the supply by the air current. When the air is sufficiently warm, this spray is evaporated and a fairly constant mixture of air and gasoline vapor is thus obtained.

The spray carbureter takes up only a small amount of space, and hence can be located to better advantage. For automobiles and motor boats, this is very important, as the space available is small and access to all parts is as necessary as in stationary engines.

STATIONARY-ENGINE CARBURETERS

22. Vaporizer.—In stationary engines, the mixing device, or carbureter, is frequently constructed as a part of the engine, and is then usually known by some other name,

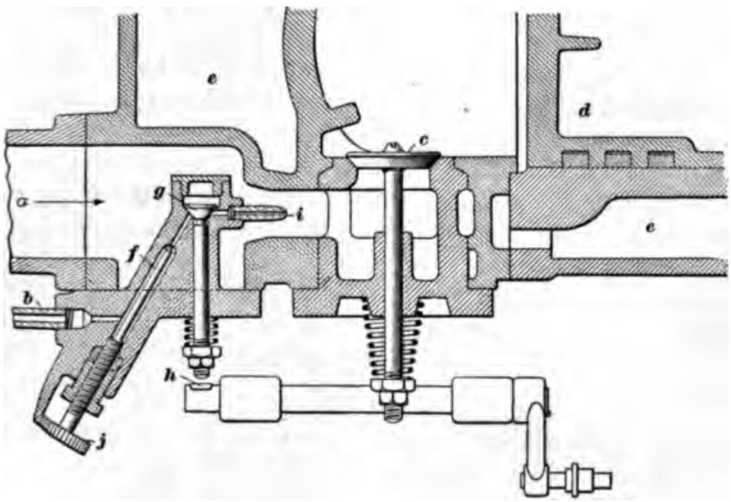


FIG. 7

ch as **vaporizer,** or **atomizer.** A vaporizer for a horizontal tionary engine is shown in Fig. 7. The air enters through passage shown at *a*, and the gasoline through the pipe *b*, nected to a gasoline tank located above the engine. e inlet valve *c* is opened automatically on the suction ke of the piston *d*. The water-jacket that surrounds cylinder is shown at *e*. The gasoline entering at *b* flows the adjustable needle valve *f* to the cone-shaped valve hich is normally held to its seat by a spring, but is

lifted or pushed forwards during the suction stroke by the tappet *h*. So long as the valve *g* is seated, the gasoline cannot pass it, but when it is open the gasoline flows from the small hole drilled in the valve seat, and, passing around the conical head of the valve, issues from the spray nozzle *i*. Here it is taken up by the air stream, which passes through the constricted passage around the spray nozzle with considerable velocity, the vaporization being aided by the conduction of heat from the engine cylinder through the surrounding metal. The function of the needle valve *f* is to regulate the rapidity with which the gasoline is drawn in by the air. The head *j* of this valve is graduated, to indicate exactly the valve opening.

23. Location of Gasoline Supply.—Usually, it is not convenient to locate the gasoline tank above the engine, since it ought properly to be buried in the ground to keep it as cool as possible and protected from the air. When that is done, the necessary head may be obtained by attaching to the engine a small pump by which the gasoline is lifted from the tank and carried to an overflow cup located above the mixing chamber. From this cup the gasoline not taken into the engine flows into a return pipe having its inlet located at the proper level in the cup, and passes back to the tank.

24. Carbureter With Water-Spray Attachment. A sectional view of the carbureter and mixing chamber as designed for the use of gasoline in engines using a water spray for cooling the combustion chamber is shown in Fig. 8. The air supply is so regulated that a certain portion enters through the passage *a*, while a sufficient amount to vaporize the fuel is admitted through the opening *b*. The fuel is supplied by a pump, operated from the engine, to a small tank *c*, in which a constant level is maintained by the overflow *d*. From the reservoir *c*, the fuel flows to a small orifice, the opening of which is regulated by the needle valve *e* which is provided with a stuffingbox for packing. The highest point of the nozzle *f*, through which the

fuel is sprayed into the carbureter, is slightly above the level of the gasoline in the reservoir *c*. The air-current, passing the nozzle *f* with considerable velocity, creates a suction at this point sufficient to draw a certain amount of gasoline, in the form of a spray, into the carbureter. After passing through several layers of fine-wire gauze at *g*, the

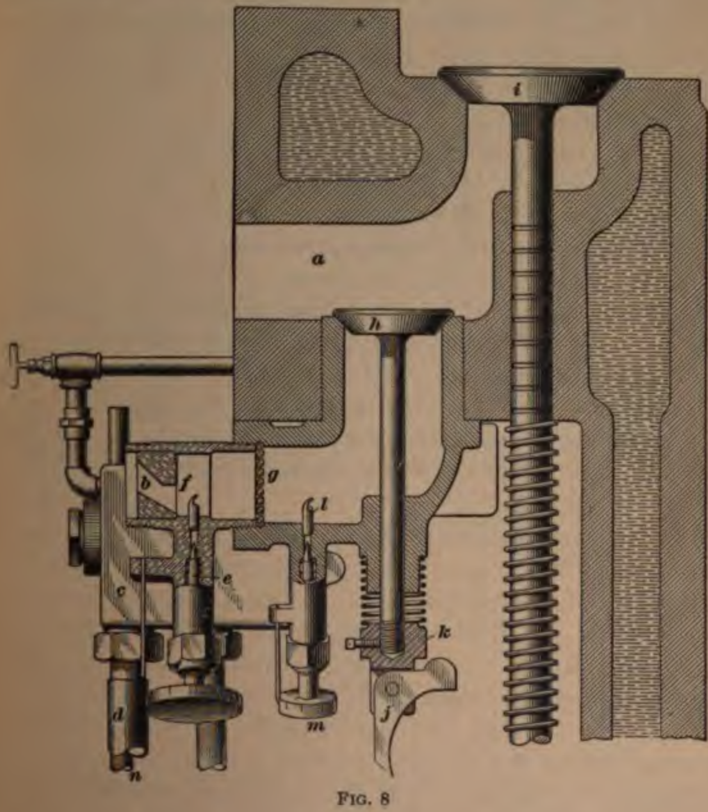


FIG. 8

air and atomized gasoline are admitted through the gasoline valve *h* into the mixing chamber *a*, where they are mixed with sufficient air to form an explosive mixture. This mixture then passes into the combustion chamber through the main inlet valve *i*.

25. The opening of the gasoline valve *h* is controlled by the governor, in order to proportion the fuel to the demands for power. The blade *j* pivoted on the valve nut *k* engages with an arm on the valve mechanism whenever the speed is normal. Under light loads, the governor moves the blade *j* out of the path of the arm; hence the valve *h* remains closed and the engine receives air only.

When working under heavy load, the engine is liable to heat up more than under light load. To avoid premature ignition under these conditions, provision is made to add a small quantity of water to the mixture of air and gasoline, which has the effect of cooling the combustion chamber. This water supply is admitted to the mixing chamber through the nozzle *l* regulated by the needle valve *m*. The gasoline vapor passes through the wire-gauze screen *g* before it meets the spray of water. The reservoir *c* is divided by a partition into two chambers, one for gasoline and one for water, the water entering through the supply pipe, connected to the tank near the top, while the excess water is carried off by the overflow pipe *n*, the amount available in the reservoir being regulated by the height of the overflow pipe that projects into the reservoir.

26. Carbureter With Hit-or-Miss Governed Gasoline Inlet.—A form of carbureter in which the gasoline-inlet valve is controlled by a hit-or-miss governing device is shown in Fig. 9. The fuel enters the cup *a* through the supply pipe fitting *b*, containing an overflow through which the surplus gasoline delivered by the pump returns to the storage tank. A float (not shown in the figure), guided in the small hole *c* in the upper part of the cup, shuts off the supply to the cup as soon as the gasoline reaches a certain level. The fuel supply to the engine is shut off by the valve *d*. The main inlet valve *e* is provided with the washer *f*, to which is connected a sleeve, guided in the casing *g* and sliding on the stem of the main inlet valve *e*. The governor is connected to the finger *h*, pivoted on the sleeve of the washer *f*, and when the governor permits the finger to

engage the nut *i*, the valve *e* on opening carries with it the washer *f*, which strikes the stem of the gasoline valve *j* and opens it. A small quantity of gasoline is thus allowed to flow from the passage and space above the valve and to enter the air passage *k* through the hole *l*. The velocity

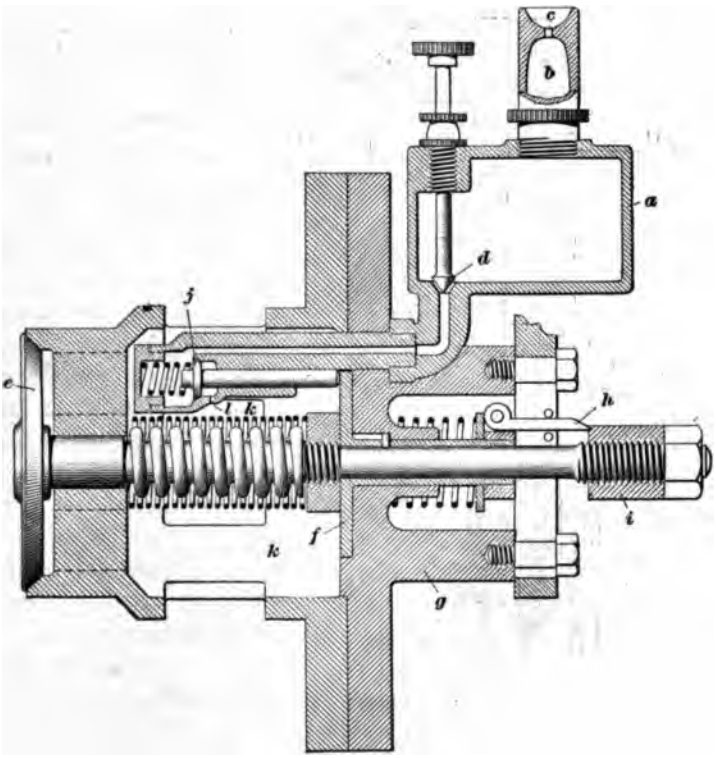


FIG. 9

of the air-current is such that the fuel, which enters the air in a fine stream, is vaporized and with the air forms a combustible mixture while entering the combustion chamber through the valve *e*.

27. Carbureter With Hit-or-Miss Governed Air Inlet.—Another arrangement for admitting and vaporizing

the fuel for a stationary gasoline engine is shown in detail in the vertical section, Fig. 10. This vaporizer does not, however, form a part of the cylinder head, but is connected some distance from it. The gasoline-valve casing *a* is attached to the air-inlet casing *b*. Gasoline is pumped from the storage tank through the supply pipe *c* into the space in the valve casing *a*. A partition *d*, dividing this space into two compartments, keeps the gasoline at a constant level, slightly below the top of the nozzle pipe *e*, the excess delivered by the pump returning to the tank through the overflow pipe *f*. A threaded needle valve *g* regulates the gasoline admitted to the valve casing *a*, while the dial valve *h* serves to shut off the supply when stopping the engine.

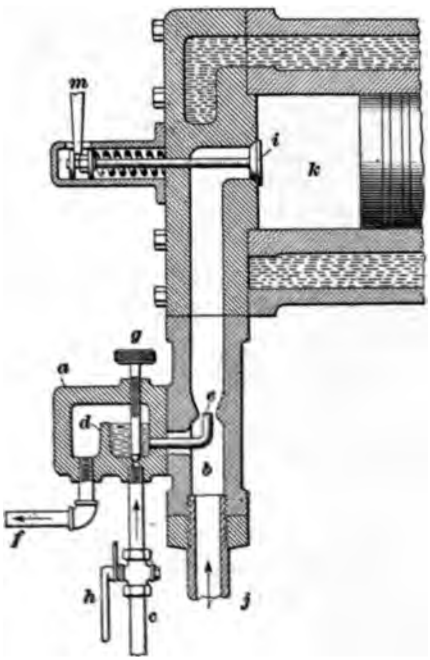


FIG. 10

The air enters the passage leading to the inlet valve *i* from the air pipe *j* which takes the air from the outside. At the point where the nozzle *e* is inserted, the area o the air passage is reduced so as to create a high velocity of th air-current at this point, resulting in a strong suction whic draws a quantity of gasoline from the casing *a* through a sma hole in the upper end of the nozzle *e*. The gasoline is th atomized by the air-current, and the combustible mixture air and gasoline vapor passes upwards into the combustic chamber *k*, through the valve *i*. It has been found that high velocity at the point where the gasoline enters the

air-current, contributes largely to the efficiency of the gasoline spray.

28. Owing to the strong suction through the inlet valve of the arrangement shown in Fig. 10, there is a possibility, especially if the inlet-valve spring should become weakened, that the inhaling action of the piston may cause the inlet valve to chatter, or open to a slight extent, even when the exhaust valve is open while no charges are needed to keep up the speed of the engine under light load. This would, of course, result in a waste of fuel, which would be drawn into the cylinder, and, forming too weak a mixture, would be expelled through the exhaust pipe without being exploded. To prevent this, the push rod that opens the exhaust valve and is controlled by the governor has an arm or extension connected by a horizontal rod to a lever *m*. When the governor causes the exhaust valve to be kept open, the lever *m* is moved in between the cylinder head and the washer on the end of the inlet valve, thus positively locking this valve and preventing it from being even slightly opened.

29. Kerosene Engine Carbureter.—A sectional view of the carbureter of a kerosene engine is shown in Fig. 11, in which the exhaust valve is shown at *a* and the inlet valve at *b*, both opening into a passage connected to the end of the cylinder. The valve *b* admits the air required for combustion; it is automatic in its action, being opened by the partial vacuum in the cylinder during the suction stroke and closed by the tension of the spring *c*. The dashpot *d* at the upper end of the valve stem is for the purpose of preventing the valve from coming to its seat too suddenly.

The needle valve *e* that admits the kerosene to the combustion chamber is operated by the lever *f*. The bushing *g* surrounds the valve and fits into the bracket *h* that is bolted to the cylinder. The nut *i* with the opening *j* is screwed into the bushing *g*, and furnishes the seat for the needle valve *e*. Between the needle valve and the bushing are brass washers *k*, perforated with small holes, through which

the oil, entering from a pipe not shown, is forced by compressed air, which enters through the pipe *l*. Cooling water is supplied to the space around the bushing *g*, entering through a pipe not shown, and passing out through the pipe *m*. The joint around the needle valve is made tight by means of

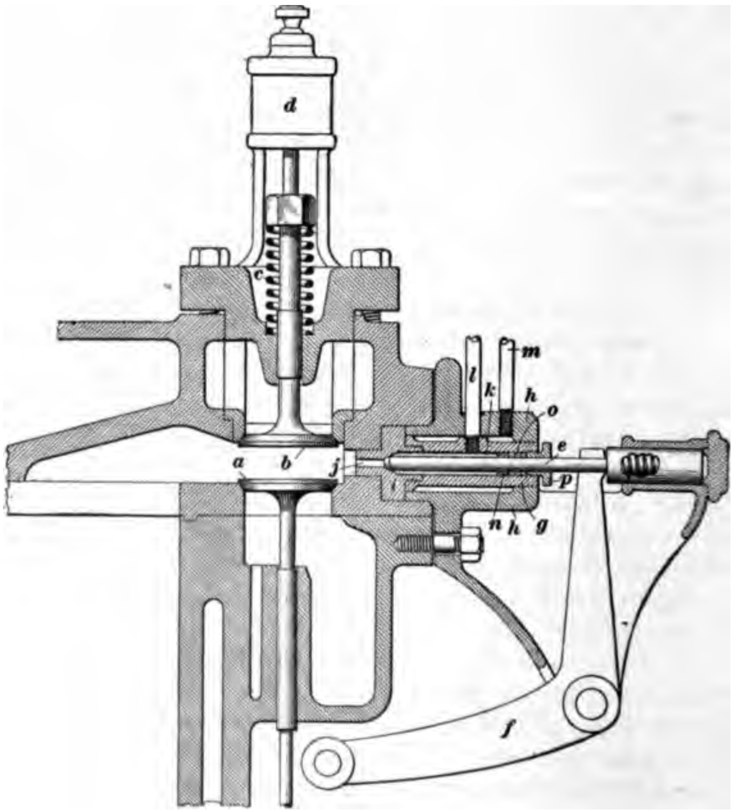


FIG. 11

the ring *n*, the packing *o* and the gland *p*. The fuel is injected into the combustion chamber at the end of the compression stroke, when the air admitted during the suction stroke has been compressed to about 500 pounds per square inch.

The fuel is injected into the highly compressed contents of the cylinder by means of air compressed to about 700 pounds per square inch, the air being furnished by a separate compressor driven by belt either from the engine or from a convenient shaft. The temperature of the air in the cylinder at the end of compression is about 1,000° F., which is considerably above the temperature required to ignite the mixture without the use of any special igniting apparatus. The oil is finely atomized by being pressed through the numerous small holes in the brass washers *k*, thus entering the combustion chamber through the nozzle in the form of a very fine spray. Owing to the high temperature of the compressed air in the cylinder when the fuel is injected, the combustion is practically perfect, leaving no residue and producing clean exhaust gases.

AUTOMOBILE AND MARINE CARBURETERS

30. The conditions under which the carbureter on an automobile must operate are more exacting than those found in connection with any other gas engine service, for the reason that an automobile motor runs at all speeds and under greatly varying loads, and the carbureter is exposed to great variations of temperatures and atmospheric conditions. It naturally follows that the simple devices found successful on stationary engines are by no means reliable when applied to automobiles, and even a successful marine carbureter may fail to give the best results, when applied to an automobile, although any carbureter found successful on an automobile will be equally successful in a motor boat.

31. Requirements for an Automobile Carbureter. A successful automobile carbureter must fulfil the following requirements:

1. It must give a practically uniform mixture, whether the demand on it is light or heavy, within the range of the speed actually attained by the motor. The mixture must be the same when the motor is running slowly with the throttle

wide open, as when going up a hill, or slowly with the throttle nearly closed, as when coasting or traveling slowly on the level, or when running at top speed with the throttle wide open.

2. It must not freeze up in cold weather, through the condensation of moisture from the air and freezing in the mixing chamber.

3. It must not be unduly sensitive to changes in the quality of the gasoline, and it must admit of easy adjustment for such ordinary variations in density as are likely to be encountered.

4. It must not be unduly sensitive to changes in the level of the car, as when climbing or descending a hill, or when turning off the road into the gutter.

5. It must vaporize the gasoline reasonably well when starting in cold weather.

6. It must operate equally well whether the motor has one or two cylinders giving intermittent suction, or a larger number of cylinders giving practically a continuous suction.

7. The quality of the mixture delivered must not be affected by the vibration of the car.

8. The carbureter must not be exposed more than necessary to the entrance of dirt, and all parts to which dirt is likely to find its way must be readily accessible for cleaning.

It is evident that with so many requirements there is no carbureter made that fulfils all of them equally well.

32. Regulation of Automobile Carbureters.—Practically all carbureters for automobile use are of the constant-level type. The gasoline passes from the tank through a needle valve to a constant-level chamber, in which the level of the gasoline is controlled by a float that acts on the needle valve, closing it when the level reaches the outlet of the spray nozzle. In this way the rate of gasoline feed to the spray nozzle is determined solely by the degree of vacuum existing in the mixing chamber, and the velocity of the air stream, irrespective of the amount of gasoline in the tank. The combined influence of the vacuum in the mixing

chamber and the velocity of the air stream is to make the mixture richer when the motor is running fast and the throttle is wide open than it is when the motor is running slowly with open throttle, or fast with the throttle partly closed. In the first case there is considerable vacuum and a high velocity of the air, while in either of the other two cases there is less vacuum and a smaller velocity of the air. This is because the throttle is located between the carbureter and the motor, and not at the carbureter intake, so that, whatever the vacuum may be between the throttle and the motor, the vacuum in the carbureter itself is reduced by the throttle valve so that only the amount of air required by the engine will be drawn in at each stroke.

The vacuum between the throttle and the motor has no effect on the amount of gasoline vaporized; this depends only on the speed of the air that is drawn through the carbureter.

The rate at which the gasoline is drawn from the spray nozzle is affected by both the vacuum and the air velocity more than it would be by either separately, so that, when neither is restricted, too much gasoline is evaporated. It is desired to keep the flow of gasoline as nearly as possible proportional to the velocity of the air, and in order to accomplish this result the newest forms of automatic carbureters restrict either the velocity of the air stream or the vacuum in the carbureter, as the demands of the motor increase.

33. Vaporizers.—In a larger number of marine engines, and in all automobile engines, the carbureter, or vaporizer, is a separate device; that is, it is not a part of the cylinder head. A simple form of vaporizer is shown in Fig. 12. The air in entering takes the course shown by the arrow, lifting the trap valve or mixing valve *a* to a greater or less extent, according to the intensity of the suction. The end of the valve has a leather pad that, when down, closes the gasoline spray orifice *b*, and when lifted, allows

the gasoline to escape. The pressure that causes the gasoline to rise in *b* is due partly to gravity, owing to the location of the reservoir, and partly to the suction of the air that picks up the gasoline and breaks it into spray as the air-current passes the orifice *b*. The gasoline comes from a tank or overflow cup above the level of the mixing valve, and its rate of flow through the spray orifice may be adjusted by the threaded needle valve *c*. The air regulating valve *d* may be opened or closed by hand. This valve admits air through the ports *e*, *e* to dilute the mixture; and by its use, the mixture may be regulated to the exact proportions required without disturbing the needle valve. Regulation of this sort may be required for a change in the speed of the engine.

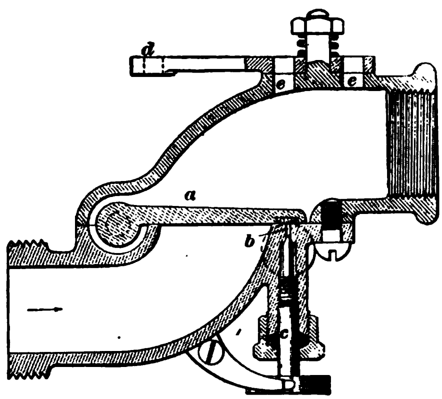


FIG. 12

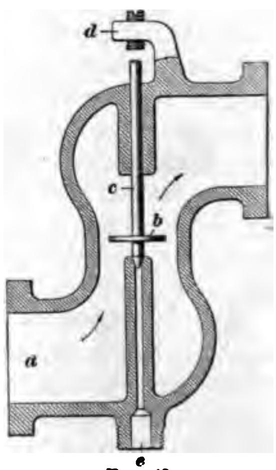


FIG. 13

34. Another simple vaporizer is shown in Fig. 13. The air enters at *a*, and, as it passes upwards in the constricted passage, it impinges sharply on the small flange *b* of the needle valve *c*, thereby lifting the valve to a greater or less extent, depending on the velocity of the air-current. In this way, the flow of the gasoline is regulated roughly according to the velocity of the air. A stop *d* is provided above the needle valve, to prevent it from lifting so high that it will not have time to close by its own weight at the

end of the stroke. The connection to the gasoline supply is made at *e*, and the gasoline rises to the needle valve by the pressure due to the height of the gasoline tank.

35. The vaporizer shown in Fig. 14 is used to a considerable extent in motor boats. Its operation depends on the

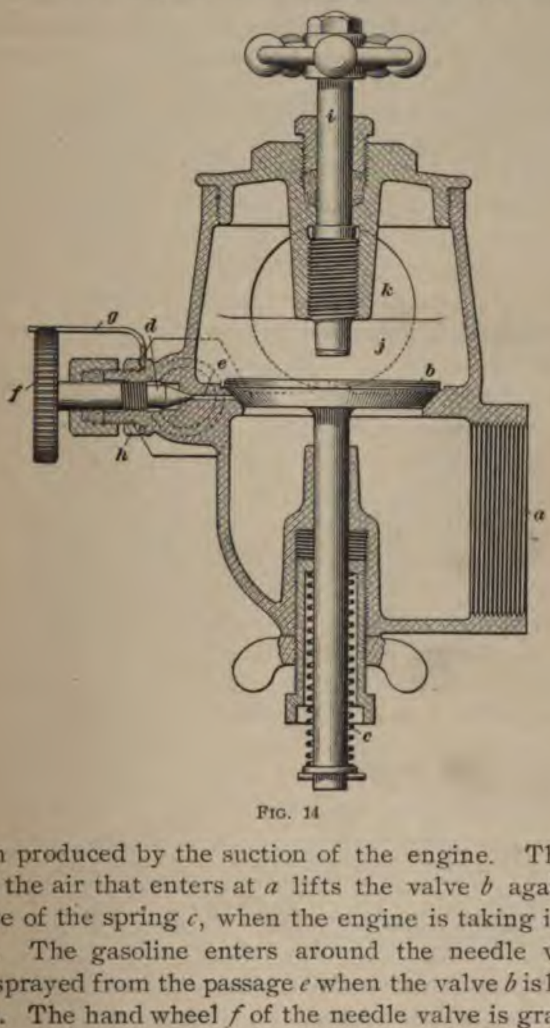


FIG. 14

vacuum produced by the suction of the engine. The pressure of the air that enters at *a* lifts the valve *b* against the pressure of the spring *c*, when the engine is taking in a new charge. The gasoline enters around the needle valve *d*, and is sprayed from the passage *e* when the valve *b* is lifted off its seat. The hand wheel *f* of the needle valve is graduated,

to indicate the opening. The pointer *g* can be moved to any position and locked there by the locknut *h*. The stop *i* can be adjusted so as to give the desired amount of opening to the valve *b*. The baffle wall *j* deflects the mixture upwards and causes it to mix more thoroughly without reducing the area of the passage *k* through which it passes to the engine. The baffle wall also serves to prevent any liquid gasoline from flowing to the engine.

36. Disadvantages of Vaporizers.—Vaporizers like the ones shown in Figs. 13 and 14 are much less common now than in the past. They are very wasteful of gasoline, and require frequent adjustment to make them supply the proper mixture. One of their most obvious disadvantages is that the gasoline will flow more rapidly to the needle valve when the tank is full than when it is nearly empty, on account of the difference in pressure due to the height of the surface above the valve. The proportion of air to gasoline is also not entirely constant when the engine speed changes, or when the engine is throttled. There is a tendency for the mixture to be too rich at high engine speeds, since the flow of gasoline is not only due to the pressure from the elevation of the tank, but is also due to the partial vacuum existing in the mixing chamber and to the velocity of the air. Even if no vacuum existed in the mixing chamber and if the gasoline had no pressure at the needle valve, the gasoline would still be drawn into the air by the velocity of the latter. It will thus be seen that there are four factors that affect the proportions of the mixture; namely, the head of the gasoline in the tank, the lift of the needle valve, the vacuum in the mixing chamber, and the velocity of the air. What is really desired is that only the last named of these four factors should be operative; or, in other words, that the velocity of the gasoline jet should be in direct proportion to the velocity of the air. This is not attained in the type of carbureter last described.

37. Float-Feed Carbureters.—The irregularity in the gasoline flow due to variations in the level of the gasoline

in the tank, is eliminated by passing the gasoline from the tank through an overflow cup attached to the carbureter, or through a chamber in which the proper fuel level is maintained by a float; so that, when the gasoline rises above the proper level, the float closes the inlet valve. This last method is used almost entirely in automobiles, and also to a large extent in motor boats.

A simple form of float-feed carbureter is shown in Fig. 15. The gasoline enters the carbureter at *a* from the supply tank, and passes through the valve *b* into the float chamber *c*. The proper level for the gasoline in this chamber is at or

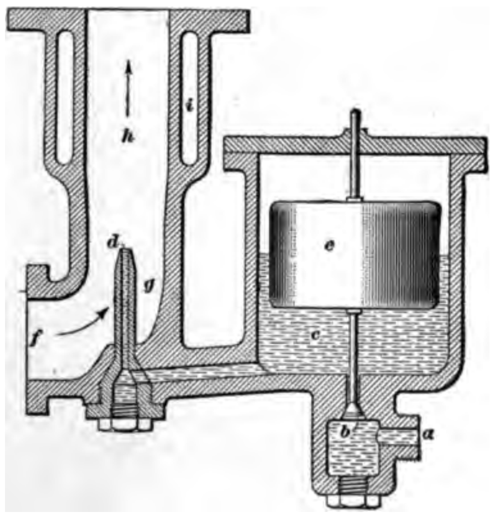


FIG. 15

very slightly below the top of the spray nozzle *d*, and when this level is reached the float *e*, which is hollow and very light, closes the valve *b*. The air entering at *f* flows with considerable velocity through the passage *g*, and, as it does so, a jet of gasoline flows from the spray nozzle *d*. This flow is caused partly by the velocity of the air-current and partly by the vacuum induced by the piston. Owing to the velocity of the air, this jet is immediately converted into fine spray in the mixing chamber *h*, and then passes

into vapor almost immediately. In order to supply the heat demanded by this extremely rapid evaporation, the inflowing air is sometimes warmed by being drawn through an air jacket around one of the exhaust pipes, or is taken from the warm space between the cylinders below the water-jacket. In other cases, the air is not warmed before it enters the carbureter, but the annular chamber *i* around the carbureter is supplied with either exhaust gases or water from the water-jacket of the engine.

38. Automatic Float-Feed Carbureter.—A modified form of the carbureter shown in Fig. 15, known as an **automatic carbureter,** is shown in Fig. 16. The gasoline

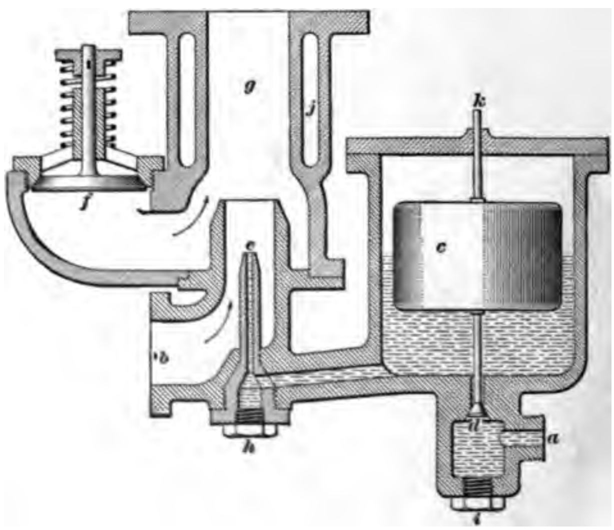


FIG. 16

comes from the tank through the opening at *a*, and the principal air stream enters at *b*. The float *c* closes the valve *d* when the level of the gasoline reaches the top of the spray nozzle *e*. When the engine is running very slowly, the air entering at *b* is all that enters the engine, but as the throttle is opened more and more, the vacuum in the mixing chamber is increased and the valve *f* is opened against

the resistance of its spring. Air is then admitted in greater or less quantity, depending on the amount that the valve *f* is opened, which, in turn, depends on the vacuum, or the speed of the engine. This air does not pass the spray nozzle, but is mixed with the carbureted air in the mixing chamber *g*. The effect of the valve *f* is thus partly to reduce the vacuum that would otherwise exist in the carbureter, thereby diminishing the amount of gasoline sucked from the spray nozzle, and also to dilute the air actually carbureted.

The two plugs *h* and *i* are provided for cleaning the carbureter of any foreign matter, as dirt and water, that may be carried in with the gasoline. As almost all such matter is heavier than gasoline and tends to settle to the bottom, it is only necessary to unscrew these plugs and cause a little gasoline to flow through. The annular jacket *j* is connected, by pipes not shown, with either the exhaust pipe or the water-jacket of the motor, and this serves the purpose of supplying the heat required by the gasoline in the process of evaporation, thus preventing condensation and freezing of the moisture in the air.

To start the motor, the stem *k* is depressed, thus opening the valve *d* and permitting the gasoline to escape freely from the spray nozzle. In this way a sufficient quantity of gasoline is allowed to gather in the intake pipe to produce, simply by evaporation, the mixture necessary for starting.

39. Another type of automatic carbureter that has proved very successful is shown in Fig. 17. The air enters at *a* and the gasoline at *b*. The height of the gasoline is controlled by the float *c* which, as it falls, presses on the levers *d*, *d*, and raises the weighted needle-valve stem *e*. When the float rises, the needle valve is closed by its own weight. As the gasoline comes from the float chamber, it issues from a number of very small slots *f* in the conical head of the spray plug *g*. This plug is drilled upwards from the bottom, and then laterally, as shown by the dotted lines, to admit the gasoline to the

space beneath a conical cover or head *h*. The division of the entering gasoline into a number of very small jets (from 10 to 16) insures a much more rapid and efficient mixing with the air than when the spray enters in a single jet. The air coming up from *a* strikes the head *h*,

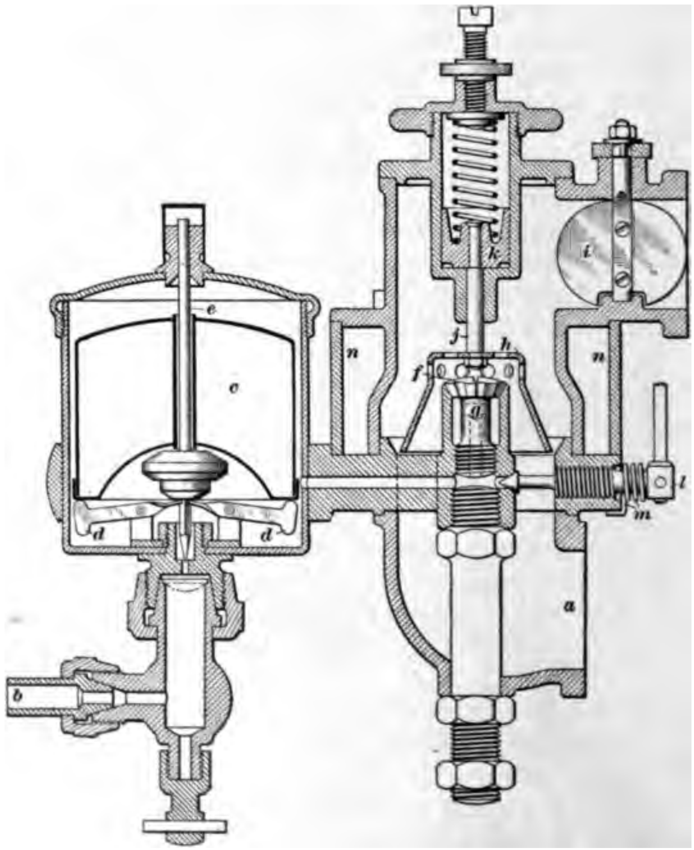


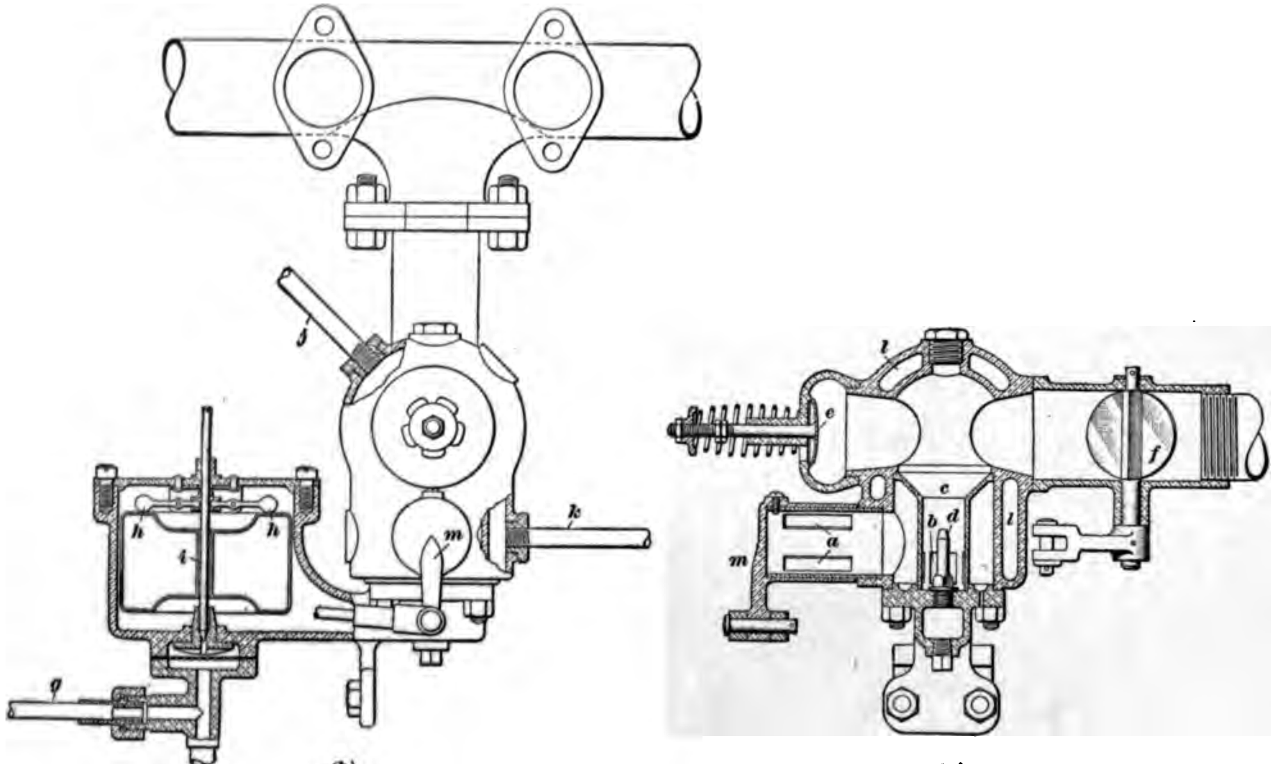
FIG. 17

which is pierced at the top with a number of small holes through which the air passes on its way to the throttle valve *i*. The cone *h* is attached to the stem *j*, to the other end of which is connected a plunger *k* working against a spring in an air dashpot. When the velocity of the air is

small, practically all the air passes up around the spray plug, and through the holes in the head *h*. When the suction increases, however, the air strikes with so much force against this head that it is lifted against the resistance of the spring, and a portion of the air is diverted and passes around the lower edge of the thimble, so that it has no effect on the gasoline spray.

Although this arrangement does not increase the amount of air drawn through the passage *a*, it gives the air an easier passage when the head is lifted, a smaller proportion of the air passes the gasoline plug, and the same result is therefore produced. As the carbureted air is divided by the holes in *h* through which it must pass, and the air that passes beneath the head flows against the stream of carbureted air on all sides, the two streams are very thoroughly mixed, which is not always the case in carbureters with automatic air-inlet valves. The purpose of the air dashpot connected to the head *h* is to check the pulsations of the latter when the engine has only one or two cylinders. Although the head is made as light as possible, it is found that owing to its inertia it does not follow perfectly the variations of the air-current when the suction is not steady. The effect of the dashpot, however, is to cause it to lift to an extent determined by about the average intensity of the suction, and to remain in practically that position from one impulse to the next. The carbureter is primed by unscrewing the valve *l* a fraction of a turn, permitting the gasoline to escape directly into the intake pipe *a*. A spring *m* insures the closing of the valve when released. The throttle valve *i* is elliptic in shape, as indicated, in order to make it unnecessary to turn it to an angle of 90° from the wide-open to the closed position. As in the carbureter shown in Fig. 15, there is a jacket *n* connected to the exhaust pipe and serving to supply the heat taken up by the evaporation.

In another form of this carbureter, a stop-screw is provided to limit the lift of the head, and a needle valve, adjustable from the bottom, is provided to restrict the rate of flow of the gasoline to the spray plug.



(b) (a)

Fig. 18 § 17

40. Another automatic carbureter is shown in Fig. 18 (*a*) and (*b*), the two views being taken at right angles to each other. The air enters through the slits *a*, Fig. 18 (*a*), in a shutter that can be rotated so as to close them, or give them the amount of opening desired. The air passes through the openings *b* in the standpipe *c* that is made small in order to give the air considerable velocity as it passes upwards past the spray nozzle. The carbureted mixture is then diluted by air coming through the automatic valve *e*, and the final mixture passes out through the throttle valve *f* into a branched mixture pipe, which bends upwards and leads to the cylinders. The gasoline enters at *g*, Fig. 18 (*b*), and the float, as it rises, causes the small levers *h*, *h* to push the needle-valve stem *i* downwards, thus stopping the flow of gasoline. By means of the connections *j* and *k*, warm water from the water-jacket of the engine is circulated through the jacket *l*, Fig. 18 (*a*), of the carbureter.

The carbureter is primed for starting by lifting the needle valve *i*, Fig. 18 (*b*). There is no needle valve acting on the spray nozzle, but the richness of the mixture is regulated by adjusting the openings of the slits *a*, Fig. 18 (*a*). This is done by means of a shutter surrounding the pipe in which the slits are cut. This shutter has openings cut in it corresponding to the slits *a*, and by rotating it the air passages are either made larger or smaller. The shutter is controlled by the operator through a lever connected to the arm *m*. By partly closing the slits, the relative amount of carbureted air is reduced and a larger proportion of air is compelled to enter through the valve *e*.

41. Carbureters With Air Inlet Controlled by Throttle.—In addition to the automatic carbureters just described, there is a large class having the auxiliary air inlet rigidly connected to the throttle so that the two open and close together. This does not secure strictly automatic action, because the speed of the engine varies with the load as well as with the throttle opening. Nevertheless, it is found in many cases to give exceedingly satisfactory results.

An early form of such a carbureter, which, however, has been little changed, is shown in Fig. 19 (*a*) and (*b*), (*a*) being a top view and (*b*) a sectional side view. At *a* is shown the float chamber; at *b*, the spray nozzle; and at *c*, a choking device equivalent to a needle valve, except that its end is blunt instead of pointed; it is carried by a screw of coarse pitch, as shown, and is raised or lowered to increase or retard the

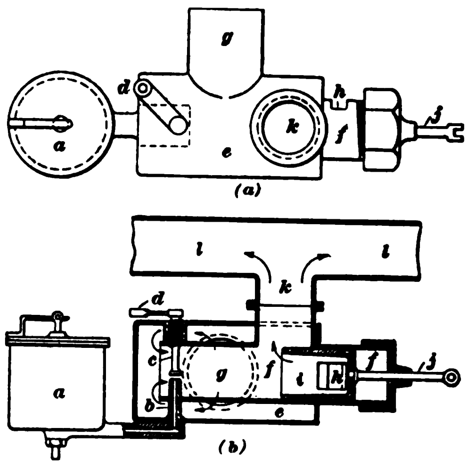


FIG. 19

flow of gasoline from the nozzle by turning the screw by means of the lever *d*. The principal stream of air is warmed by passing around the exhaust pipes, and enters the annular chamber *e* by the pipe *g*, and, following the direction of the arrows, it is drawn past the spray nozzle *b* and up into the branch pipe *l*, which leads directly to the inlet valve chambers of the engine cylinders. The auxiliary stream of air enters by the slot *h* in the tube *f*. Inside this tube is a slotted shutter or sleeve *i*, with the right-hand end closed and connected to the stem *j*. When the shutter is moved to the left or right, it will partly cover or uncover the slot *h*, and at the same time, by moving to the left, it partially obstructs the passage both of the carbureted air and of the auxiliary stream of air before they pass into the pipes *k*, *l*.

42. In another carbureter, a by-pass controlled by a throttle furnishes the auxiliary or diluting air stream. This throttle is connected to the main throttle, but there is also a valve controlling the entrance of the air to the spray chamber. This valve, by lifting when the velocity of the air increases, tends to keep the suction in the spray chamber more nearly constant than would otherwise be the case. Fig. 20 shows

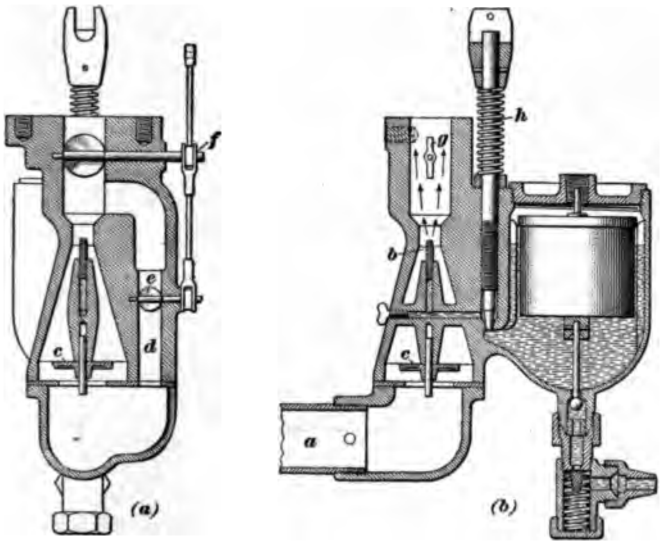


FIG. 20

two sectional views of such a carbureter, the two views being taken at right angles to each other. The intake for both the main and the diluting air streams is shown at *a*, Fig. 20 (*b*). The spray chamber is greatly contracted about the spray nozzle *b*, to give the air a high velocity, in order that the gasoline may be drawn freely through the spray nozzle. The air valve *c* is shown wide open. The auxiliary air stream passes up through *d*, Fig. 20 (*a*), past the butterfly valve *e*, which is controlled by the links and levers at *f*, attached to the main throttle *g*, Fig. 20 (*b*). The passage of the gasoline from the float chamber to the spray nozzle is controlled by the needle valve *h*, which is regulated by the operator.

43. Central-Feed Carbureters.—The carbureter shown in Fig. 21 has several advantages over the one shown in Fig. 16. Instead of the spray chamber *a* and float chamber *b*

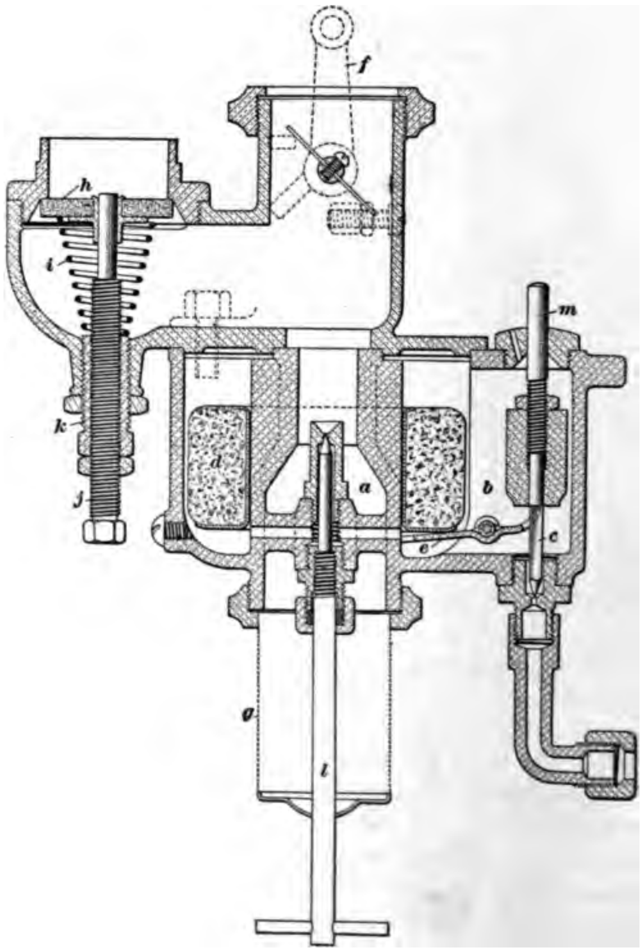


FIG. 21

being entirely separate, the spray chamber is located inside the float chamber. By reason of this arrangement, the carbureter is not affected by tilting, which might cause the

gasoline to overflow from the spray nozzle or to require considerable suction to lift it to the top of the nozzle. Also, the needle valve *c*, controlling the entrance of the gasoline to the float chamber is closed by the weight on its stem, instead of directly by the annular cork float *d*, whose function it is to raise the weight through the action of the lever *e*. As the arm of the lever connected to the float is much longer than that acting against the weight, a much more positive closing of the valve is secured than if the float were to act directly on the valve.

In this device, the throttle is made a part of the carbureter, and is operated by the lever arm *f* at the top. The principal air stream enters at the bottom through the wire-gauze dust screen *g* and passes upwards past the spray nozzle. The auxiliary stream enters by the automatic inlet valve *h*, which opens downwards against the spring *i*. This valve is composed of a fiber disk, with a brass bushing guided by the stem of the screw *j*. The threaded bushing *k* may be adjusted to vary the tension of the spring *i*. The spray opening is regulated by the needle valve *l*. The carbureter is primed for starting by raising the stem *m* of the needle valve. As the weight is attached to this stem by means of a screw thread as shown, the weight may be screwed up or down, and the level at which the float will act on the gasoline valve will be altered. For example, if it is found that the float does not close the valve until the gasoline has reached too high a level, it may be adjusted by screwing the weight upwards on the stem, which will permit the valve to close when the float stands in a lower position.

44. A section of a type of carbureter used in both automobile and marine practice is shown in Fig. 22. It differs from those previously shown in a number of particulars. The gasoline enters at *a* and the air at *b*, which in the carbureters previously shown would naturally be the outlet. The air therefore flows downwards past the spray nozzle, instead of upwards as is more usual, and passes through the throttle valve and out at *c*. The float *d* is shaped so that it

goes on each side of the mixing chamber. It is secured to a lever pivoted at the right, and rising closes the needle valve *e*. In the passage *b* is an automatic air-inlet valve *f*, closed by means of a spring *g*, as shown. This valve does not entirely

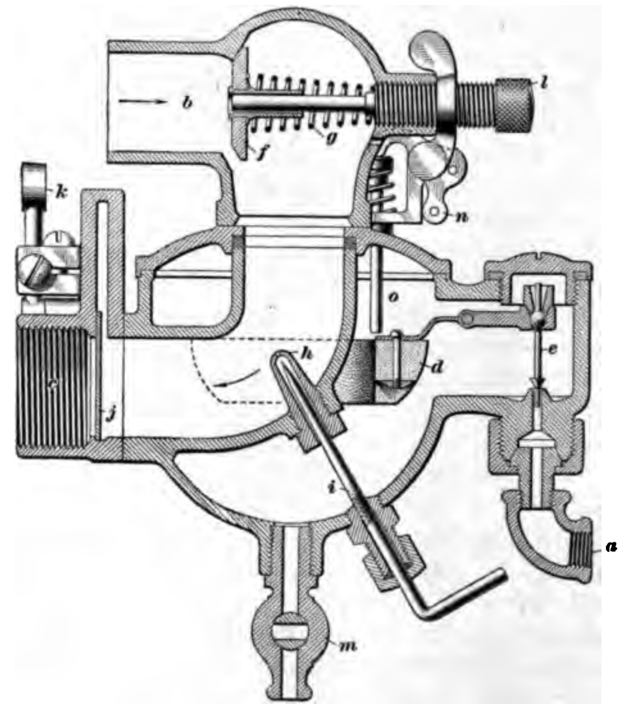


FIG. 22

close the air passage when it rests against its seat, but at the bottom is left an opening through which is supplied the necessary air for keeping the motor in operation under the slowest running conditions. As the suction increases, this valve opens against the spring *g*, thereby admitting a larger quantity of air.

The gasoline passes directly from the float chamber to the spray nozzle *h*, the opening of which may be regulated by the needle valve *i*. As the opening of this nozzle is exactly in the center of the float chamber, the carbureter is not

affected by being tilted. The throttle valve *j* is opened and closed by means of the lever *k*; the mixture of air and gasoline passes through in the direction indicated by the arrow. Adjustment of the automatic air valve *f* is obtained by modifying the tension of the spring *g*, by screwing up or unscrewing the shouldered stem *l*, which extends through the valve *f* to guide it, but is not attached to it. A drain cock *m* is provided at the bottom of the float chamber, for the purpose of emptying or for drawing off water that may have got into it.

In starting the engine, the float *d* is depressed by means of the lever *n*, which depresses the pin *o*. This allows the level of the gasoline to rise above the nozzle *h*, when enough gasoline enters the air passage to start the engine. This is known as a *priming device*.

CARBURETER ADJUSTMENT

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45. A carbureter may deliver too rich a mixture or too weak a mixture, at all speeds within the range of operation of the engine. More often, however, a mixture will be rich at certain speeds, high or low, and either normal or, possibly, too weak at other speeds; or it will be weak at high or low speeds and normal or too rich when the speed is changed. Owing to the large number of types of carburèters, no definite rules that will apply to all can be made for their adjustment. If the printed instructions of the maker are at hand, they should be followed. If these should fail to give the desired result, an observance of the following general principles may aid in correcting the trouble.

1. A non-automatic carbureter will tend to take proportionally more gasoline at high than at low speeds. If adjusted correctly for low speeds, it will be wrong for high speeds, and vice versa.

2. A needle valve acting on the spray nozzle does not produce automatic regulation; it reduces or increases

the gasoline feed in substantially the same ratio for all speeds.

3. A fixed shutter over the air intake does not produce automatic regulation. By partly closing it, the suction in the spray chamber is increased and the amount of air supplied is reduced, thereby increasing the richness while reducing the volume of the charge.

4. To obtain a uniform mixture with a carbureter that is not automatic, the gasoline feed at high speeds must be restricted, or the air must be allowed to enter more freely, to diminish the suction in the spray chamber. Some carbureters are arranged to by-pass a portion of the air around the spray chamber at high speeds. If the by-pass valve controlling this action is connected to the throttle, the type of carbureter will be like those shown in Figs. 19 and 20.

5. In an automatic carbureter, opening the needle valve or reducing the air-intake opening will give a richer mixture at all speeds.

6. In an automatic carbureter, reducing the spring tension on the auxiliary, or diluting, air valve will permit this valve to open wider, especially at high speeds, and will therefore make the mixture weaker at high speeds. The same principle holds good regarding the spring tension on such a device as the head or thimble, shown in Fig. 17, that permits a portion of the air to pass around the spray chamber. Increasing the spring tension makes the mixture richer at high speeds.

7. A weaker mixture may be obtained at low speeds by increasing the spring tension on the automatic or auxiliary valve and enlarging the main air intake; or it may be obtained by increasing the spring tension and partly closing the needle valve. The latter arrangement will not give as full charges as the other, as the resistance to the ingoing charge will be greater, but if the carbureter is large for the engine it may give better vaporization on account of the higher air velocity past the spray nozzle.

8. If at high speed richer charges are desired, the throttling effect due to increasing the spring tension on the

automatic valve may be offset by increasing the opening of the main air intake. The needle valve also should be opened further, to avoid the necessity of restricting the automatic valve unduly. At low speeds, the increased openings of the main intake and the needle valve will neutralize each other as regards the proportions of the mixture.

9. If the automatic valve is provided with a stop, its effect will be to render the carbureter non-automatic at speeds above those at which the automatic valve comes against the stop. For this reason, reliance should be placed on the spring where possible, rather than on the stop. The chief function of the stop should be to prevent the valve from opening under sudden pulsations so far that, by reason of its inertia, it cannot close promptly.

10. A slightly weak mixture burns faster than a normal or a rich mixture. This, therefore, is the best mixture for high speeds. When, however, the motor is working under a heavy load, a slow-burning mixture is better, as it maintains a higher pressure on the working stroke. The ideal carbureter adjustment, therefore, should give a normal mixture, or one very slightly rich, at the slowest speeds, and a weaker mixture at high speeds.

11. Occasionally, a change in carbureter adjustment is made necessary by a change in weather or in the quality of the fuel. Such changes are properly made in the main air or needle-valve openings, since the changes must be the same for all speeds.

12. In order to have correct adjustment, the gasoline level in the float chamber must be at or slightly below the spray orifice.

46. Adjustment of New Automobile or Marine Carbureter.—In adjusting a new carbureter, the first thing to do is to see that the gasoline level is at the right height, which it probably is. If not, examine the float to see that it is working properly and is set correctly. Next see that the igniting device produces a good strong spark, and then follow the instructions of the maker regarding the

setting of the needle valve, main air intake, and automatic valve. Prime the carbureter freely, and start the engine. Run it throttled to about half speed at first, with suitable spark lead, and gradually reduce the opening of the needle valve, a little at a time, until the engine shows signs of running weaker. Then open it to the point where the engine runs best. If the engine starts, but will not keep on running, it is getting either too much or too little gasoline, probably the latter. The former will be indicated by black smoke in the exhaust, and probably a very loud exhaust due to slow combustion. If there is no black smoke, but the motor will not run, try increasing the needle valve opening, a little at a time, until the motor runs steadily, after which adjust as before.

Now open the throttle a little, and note the result, as the engine runs up to or a little beyond its maximum speed. If it weakens, it is probably getting too much gasoline. Relax the spring on the automatic valve, and try again. Watch for black smoke, but remember that this appears only when the excess of gasoline is considerable. If necessary, open the needle valve and readjust the main air intake. Try also closing the throttle until the motor barely runs, retarding the spark, and note how quickly it responds as the throttle is opened. A little further experimenting along the lines just indicated will result in an adjustment sufficiently correct to allow the engine to be run in regular service, after which it is comparatively easy to discover what changes will produce the best mixture.

ELECTRIC IGNITION DEVICES

IGNITION SYSTEMS

MAKE-AND-BREAK IGNITION

1. If the ends of two wires forming part of an electric circuit are brought in contact, thereby closing the circuit, and then quickly separated, a bright spark will be produced as the contact is broken. This phenomenon underlies the operative principle of what is known as the **make-and-break system of ignition,** with which it is necessary first to complete the electrical circuit through the spark-producing mechanism, or **igniter,** and then break the circuit to obtain a spark for igniting the charge. In stationary gas-engine practice, the simplest kind of igniter uses city lighting current, with an incandescent lamp in series in order to prevent the current from being too strong, and consists simply of a mechanical device for making and breaking the circuit in the combustion chamber at the proper moment.

2. In Figs. 1 and 2 is shown an elementary make-and-break ignition device. In Fig. 1, *a* is a shaft turning at one-half the speed of the engine, or, if the engine is of the two-cycle type, it turns at the same speed, and may, in fact, be the engine crank-shaft itself. On this shaft is a cam *b*, frequently called a *snap cam,* that bears against a plunger *c*, held in contact with the cam by the spring *d*. The upper end of this plunger has an adjustable head *e*, against which

bears a finger f, secured to a rocking stem g. This stem g passes through the wall of the combustion chamber, and near its inner end it has a ground flange to prevent the gases from blowing past it. The inner end is prolonged in the finger h, that makes contact with an insulated stem i, to whose outer end one of the wires of the electric circuit is attached. The light spring j holds the finger h against the stem i, except when the two are separated by the pressure of the head e against the finger f. In Fig. 2 is shown a view of the parts f, g, h, and i taken at right angles to the view in Fig. 1. Because the greater tension of the spring d overcomes that of the spring j, the contact points are normally out of contact except when the plunger is pushed up by the cam. The adjustment of the head e is such that after contact has been made it leaves the finger f, and continues its upward motion a short distance, so that, when the plunger snaps off from the cam, the head strikes the finger a smart blow, thereby causing an abrupt separation of the contact points. By reason of this abrupt separation, the contact points are saved from being burned or fused by the arcing of the current that would otherwise occur. In spite of this precaution, however, the contact points deteriorate rapidly from the intense spark; consequently, an electric-light current is used for ignition only when dilute gas is used—such as producer or blast-furnace gas, both of which ignite with difficulty—or in large engines, where reliability of ignition is of more consequence than the burning of the contact points.

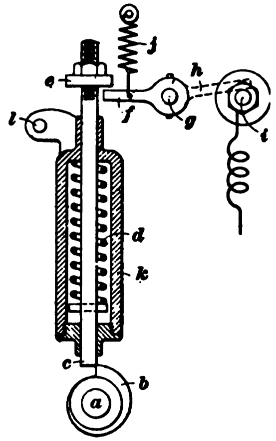


FIG. 1

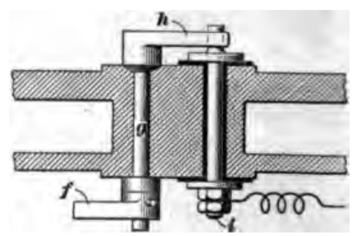


FIG. 2

3. Fig. 3 shows an igniter plug for a stationary engine as it appears when removed from the cylinder head. To avoid corrosion and consequent sticking in the cylinder head, the plug *a*, which enters the head, is usually made of brass. It contains the stationary electrode *b* and the movable electrode *c*, both being fitted with platinum tips at the points of contact. The fixed electrode *b* is insulated from the plug by means of bushings made of porcelain, lava, mica, or some similar insulating material. If of porcelain or lava, they are made tight against the pressure of the explosion by asbestos-packing washers between the faces of the insulators and the collar of the electrode, the countersunk portions of the plug in which the bushings are fitted, and the nut *d* that holds the electrode in place. The movable electrode *c* has a long stem *e* passing through the plug, and has an interrupter lever *f* fitted loosely on it. A stop-lever *g* is held firmly on the stem *e* by means of a cotter *h*, passing through the lever and stem, and a spiral spring *i* fastened at one end to the interrupter lever *f* and at the other end to a pin passing through the extreme end of the electrode stem *e*, the spring being twisted so as to cause its tension to press the blade of the interrupter lever *f* against the arm of the stop-lever *g*. A stop-pin *j* attached to the inner end of the igniter plug limits the space between the two points of contact when the electrodes separate.

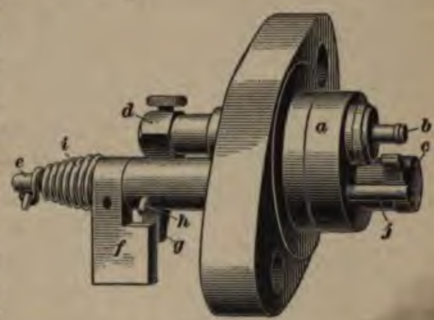
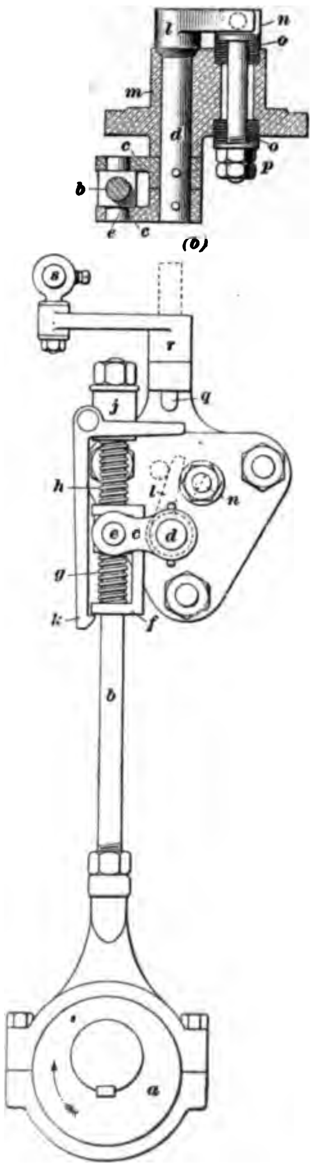


FIG. 3

The spark is produced by rotating the interrupter lever *f* about the axis of the stem *e* to a point beyond that at which the igniter points *b* and *c* are in contact. When these points meet, the stem *e* ceases to rotate and the lever *f* and arm *g* are separated, while some additional tension is also put in the spring *i*. When the lever *f* is released, the spring *i*



(a)
FIG. 4

causes the lever to return, striking the arm *g* a sharp blow and causing the igniter points to be quickly separated, thus producing the spark.

4. While, in application and principle of operation, the make-and-break igniters used on different marine engines are very much alike, they are very dissimilar in details of construction. A front elevation and a horizontal section of one form of igniter used on a four-cycle marine engine are shown in Fig. 4 (*a*) and (*b*). The ignition mechanism is operated by means of an eccentric *a* that actuates the igniter rod *b*. The latter is attached to the arm *c* of the movable electrode *d* by means of a trunnioned block *e* held in place by the yoke or igniter hammer *f* and the springs *g* and *h*, the latter immediately under the head-end *j* of the igniter rod, as shown. The igniter trip, or latch, *k* is pivoted on the igniter-rod end *j*. As shown in Fig. 4 (*b*), the arms *c* are pinned to the outer end of the stem of the movable electrode *d*, whose contact arm *l* is provided with a ground beveled seat or taper fit in the igniter bonnet *m*. The stationary electrode *n* is insulated from

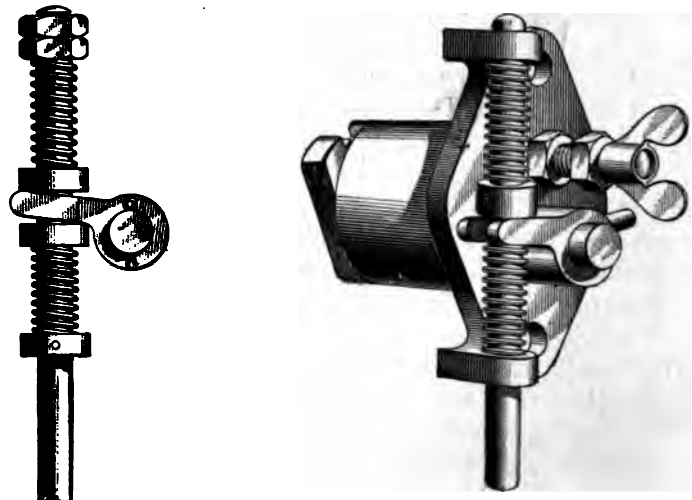
the igniter bonnet by means of mica disks *o* fitted into recesses in the igniter bonnet and held in place by a washer and nuts *p*. On the contact arm *l* and on the inner end of the stationary electrode *n* are contact points, shown dotted in Fig. 4 (*a*), of platinum, nickel steel, or other material that does not oxidize readily under heat.

When the eccentric *a* moves in the direction of the arrow, the igniter rod *b* will rise, carrying with it the yoke or hammer *f*, compressing the springs *g* and *h*, and lifting the igniter block *e* so as to carry the inner arm of the movable electrode into contact with the contact point of the stationary electrode and thus close the circuit. Further upward movement of the igniter rod serves simply to increase the tension of the springs *g* and *h*, so that, when the horizontal arm of the latch *k* comes in contact with the igniter pin *q*, and the latch *k* is thereby thrown away from the hammer yoke *f*, the latter will descend quickly on being released. The rapid descent of the hammer *f* causes a sharp blow to be struck on the igniter block *e*, resulting in a quick break of the contact between the movable and stationary electrodes, and thus producing a spark that ignites the charge.

5. To run an engine at varying speeds, it is necessary, in order to obtain the best results, to modify the time of ignition to suit the speed, making the time earlier for high than for low speed. It is also necessary to modify the time of ignition, according to the load the engine is carrying, if the engine is regulated by throttling. In other words, with a given speed, a charge will burn faster if highly compressed, as when a full charge is taken, than if only slightly compressed, as it may be if the charge has been much throttled. For these reasons, all automobile engines and a great number of launch engines are provided with means for varying the time of ignition. The time of ignition can be varied with the primary ignition device shown in Fig. 1, by pivoting the guide *k* at *l* and swinging it a little to the right for a later spark, and to the left for an earlier spark.

6. With the igniter mechanism shown in Fig. 4, the time of ignition is regulated by means of an adjusting lever *r* operated by a horizontal rod *s*. Forward motion of the lever *r* raises the threaded igniter pin *q*; while a rearward movement lowers it, thus advancing or retarding the time of tripping the latch *k* and hence the time of ignition.

7. Of many simpler devices than this, it is necessary to mention but one type, operated by a straight spring-returned igniter rod that, in turn, is actuated by a cam of any desired



(*a*) (*b*)

FIG. 5

shape. The igniter rod passes through a flat rocker lever. There is a flat washer on each side of the rocker-arm, with springs held by collars or threaded nuts above and below. In action, the igniter rod rises, and the rocker-arm, washers, and springs assume the position shown in Fig. 5 (*a*) when the contact within the cylinder is made. The rod continues to rise until it is tripped at the time of ignition by any suitable means. The rod, lever, springs, and washers then assume their normal positions, the igniter points

separate, and ignition takes place. Fig. 5 (*b*) shows a modified form of this simple ignition mechanism.

In a large number of two-cycle marine engines on the market, the insulated electrode is not mounted in a removable bonnet with the moving electrode, the usual construction being to have the insulated electrode inserted through the cylinder head.

8. With a low-voltage current, such as that derived from a primary battery, a spark coil must be employed to produce the necessary electric tension or voltage for the spark. When a battery and spark coil are employed, the abruptness of the break between the contact points serves to increase the intensity of the spark, it being largely proportional to the sharpness of the circuit rupture. In Fig. 6 is shown an elementary wiring diagram for a primary ignition circuit, with the direction of the current shown by arrows. When the timing cam *a* brings the points *b* and *c* into contact, the current flows from the battery *d* through the switch *e* (when closed), the spark coil *f*, the insulated electrode *g*, the rocking contact finger *h*, and the grounded contacts *i*, *i*, back to the battery. The grounded connections *i*, *i* may be made to the frame of the machine, or any other convenient metallic return may be used.

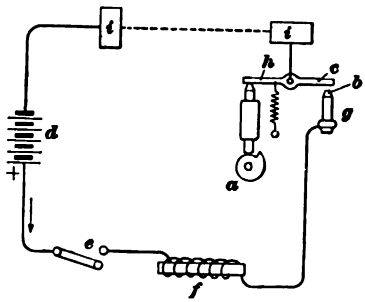


FIG. 6

JUMP-SPARK IGNITION

9. The mechanism of the make-and-break system of ignition requires a considerable number of moving parts that are more or less objectionable in an automobile engine, and the majority of automobile builders prefer to use what is known as the jump-spark system of ignition, in which the primary current is converted by an induction coil into a secondary

current of sufficiently high tension to cause a spark to jump an air gap. With this system, a revolving contact timer is employed in place of the snap cam *b* shown in Fig. 1. As there are no other moving parts, the whole apparatus is extremely simple.

10. In the diagram, Fig. 7, are shown the essential elements of a jump-spark system of ignition. Here *a* is the battery, *b* is a switch for opening the primary circuit when it is not in use, and *c* is a revolving timer turning at one-half the speed of the crank-shaft, if the engine is of the four-cycle

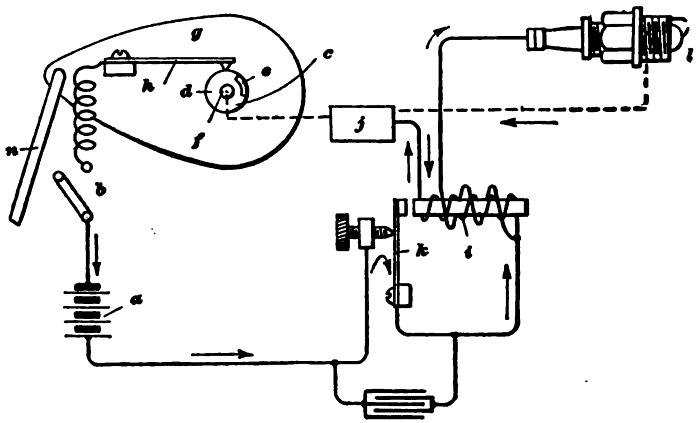


FIG. 7

type. The timer in the elementary apparatus shown consists of an insulating ring *d* mounted on the shaft and having dovetailed into it a copper or brass segment *e*, in electrical connection, by a screw or otherwise, with the shaft *f*. A plate *g* is mounted loosely on the shaft, so that it does not turn with it, but may be rocked about it through a suitable arc, say 45°. Mounted on this plate, and insulated from it, is a brush *h*, that bears against the insulating ring and makes contact with the metal segment at each revolution of the latter. The primary winding of the spark coil is represented by *i*, and *j* is the ground on the engine. A **trembler** *k*, similar to an electric buzzer, is provided so that the current may be rapidly interrupted. The trembler

is exactly like the interrupter or vibrator of a Ruhmkorff coil, and its purpose is both to interrupt the current more rapidly than could be done by the timer and to produce a stream of sparks instead of a single spark only.

11. The course of the current is from the positive pole of the battery to the trembler, then to the primary winding of the spark coil, the engine frame *j*, through *e* to the brush of the timer, when contact is made, and finally through the switch *b* to the negative terminal of the battery. The negative terminal of the secondary winding of the coil is connected to the battery terminal of the primary winding, and the positive secondary terminal is connected to the insulated member of the spark device, or **spark plug,** from which, after jumping over the gap *l*, the current returns to the coil by way of the engine frame *j* and primary winding. When the circuit is closed by the timer, a stream of sparks passes between the spark points *l*. For use with small, high-speed motors, the coil vibrator is frequently omitted, and a snap or vibrating form of timer is used that gives a quick break but only one spark.

12. As in the Ruhmkorff coil, the primary winding is provided with a condenser *m*, which serves the double purpose of increasing the abruptness of the circuit rupture, thereby increasing the intensity of the secondary spark, and of absorbing the current that otherwise would produce a hot spark at the trembler contacts, and soon burn them out. It will be remembered that the function of a condenser is to absorb the extra current induced in the primary coil at the moment of rupture. Under the primary system of ignition, it is precisely this extra current that produces the useful spark in the engine; but in the secondary system, this extra current is objectionable, because it dies down so slowly that it fails to induce a sufficiently intense spark in the secondary coil.

The change of the time of ignition is accomplished for different speeds by rocking the plate *g* to the right or left by means of the rod *n*, so that contact is made by the timer early or late in the revolution of the shaft.

CONSTRUCTION AND APPLICATION OF IGNITION DEVICES

BATTERIES

PRIMARY BATTERIES

13. With small engines, the source of the ignition current is commonly a battery, which may be primary or secondary according to conditions. If the engine is stationary, the battery is commonly an Edison-Lalande or other oxide-of-copper battery. For marine motors, storage batteries are sometimes used, and sometimes also the oxide-of-copper batteries, but the most common source of current is the dry cell, which is now made in certain forms with very high efficiency and long life. For automobiles, the battery is either of the primary dry-cell type just mentioned or of some special type of storage battery.

14. When dry primary cells are used, the number necessary will depend on the winding of the spark coil and the size and condition of the cells. Some coils wound for dry primary cells require a higher voltage than others, and the internal resistance of the cells has also a considerable influence. Dry primary cells can now be obtained that, even in the small, or 6-inch size, i. e., measuring 6 inches in height, will, when fresh, test over 25 amperes on short circuit. Of these fresh cells, generally four or five, sometimes even three, will be found sufficient; but, as they approach exhaustion, one, two, or three more must be added. The first cells of the set are thrown away when spent, and fresh ones put in their place, while the last cells are still useful. A good

rangement is to have two sets, of from five to eight cells ıch, arranged so that current may be taken from either set.

While four dry-battery cells when new will ignite the ıarge, it is customary to use from six to eight cells. With :oper care and adjustment to the proper length of contact ır make-and-break ignition, a set of cells in a motor boat ill sometimes last two seasons or more, while dry cells acci- entally short-circuited and left 2 or 3 hours will be ruined.

No matter what type of battery is used, in motor boats r elsewhere, the cells should be kept dry, and a reserve set hould always be kept on hand for use in case of failure rom any cause. A very large proportion of drifting boats, ometimes in dangerous places, are disabled as a result of xhausted batteries.

CARE OF PRIMARY BATTERIES

15. The only care a primary dry battery requires is to test t occasionally with an ammeter to determine the condition of he cells. This should be done *one cell at a time*, with a ocket ammeter such as is shown n Fig. 8. The instrument is ısed by touching the part marked *arbon* to the carbon (positive) erminal of the battery, and the nsulated cable *a* to the zinc negative) terminal, which short- ircuits the cell. The particular nstrument shown indicates both olts and amperes, the latter nly when the button *b* is pressed. 'he button should be pressed for n instant only, barely long enough to allow the needle to ome to rest, as the battery is very rapidly depleted by ıort-circuiting.

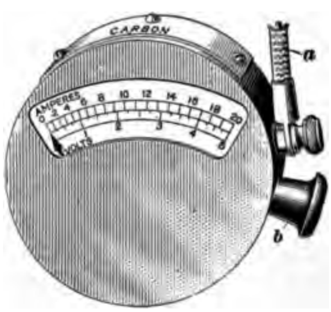


FIG. 8

Occasionally, the battery box used on automobiles for ılding the cells should be opened and the nuts of the bind- g posts tried with the fingers to see that they have not

worked loose. It is well also to examine the flexible battery connectors, since, if these are of the ordinary ready-made sort, they are probably too short to have sufficient flexibility unless the battery cells are packed very tightly, so as to entirely prevent them from shaking. Any vibration of the cells will, in time, break the connectors. As this generally occurs inside the insulation, it is a difficult thing to locate, and it is best detected by substituting a fresh connector for any one that, when tried by bending it in the fingers, appears to be broken.

16. Good battery connectors may be made up from No. 16 flexible lamp cord in 8-inch lengths. The cord is untwisted for the purpose, and each length makes two connectors. The ends of the cords are scraped for a length of about 1 inch, and the bare wire twisted and doubled on itself. The wire is then slipped through a terminal or copper connector of the form shown in Fig. 9, the bare end being run through the stamped loop *a*. The loop is then hammered flat, the wire doubled back upon itself, and the clips *b*, *b* bent over the insulated part of the wire with a pair of pliers. The wire is then coiled around a lead pencil.

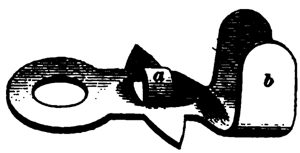


FIG. 9

If the binding posts on the battery cells show a tendency to work loose, the nuts may be locked with nuts taken from discarded cells. If, however, the wire connections are flexible, such as those just described, and the cells do not shake about, there will be little tendency on the part of the nuts to work loose.

17. In testing a primary battery, it should be remembered that on standing the cells will recuperate sufficiently to show on test a strength apparently sufficient for a considerable mileage; but if they are nearly discharged they will go down again in a few miles and cause the engine to miss explosions apparently without reason. If there is reason to

think that the battery is nearly spent, the cells should be tested after the car has been run 5 or 10 miles. If they show less than 5 amperes on short circuit they are not worth keeping, unless the spark coil is very efficient. Since a primary battery will recuperate somewhat on standing, the possession of two sets of cells, both of which are nearly exhausted, enables the operator to keep the engine going for some time by switching alternately from one battery to the other. When that expedient fails, the two sets may be recoupled in series and used a little longer.

SECONDARY, OR STORAGE, BATTERIES

18. The majority of the storage batteries used for ignition purposes are similar in construction to those used for vehicle propulsion, but of smaller capacity; but there are also a few dry storage batteries in which the acid solution is mixed with silicate of soda, by which is produced a sort of jelly that is not subject to the risk of spilling. When liquid cells are used, they are, of course, sealed, and have a rubber screw plug in the top with a small vent through it for the escape of gases produced in charging. By unscrewing the plug, a syringe can be introduced to take out a portion of the liquid for the purpose of testing its density with a hydrometer.

The storage-battery equipment of an automobile almost invariably consists of two sets of two cells each, but occasionally three cells are used. The negative terminals of both sets are connected together, and the positive terminals lead to independent terminals on a two-throw switch, so that either battery may be used at will, while the other is held in reserve until the first is discharged.

19. When a storage battery weakens to such an extent that explosions are missed, it can no longer be used until recharged, for storage batteries do not recuperate when put out of service and allowed to stand. A storage battery discharges itself slowly, and when it is partly discharged it

loses its strength much more rapidly than when fully charged. For this reason, a storage battery should be used continuously until it is discharged before the other battery is put into service. A storage cell is discharged when its voltage on open circuit has dropped to 1.8 volts. Down to this point the voltage will drop rather slowly, but with increasing rapidity as the end is approached, and from 1.8 the voltage falls off with extreme rapidity.

A storage battery is tested by testing its cells individually with a voltmeter, an ammeter being useless for this purpose, and it should be recharged as soon as the voltage of either cell has fallen to 1.8. It is, in fact, best to recharge a little sooner than this, in order to avoid being unexpectedly stranded, and for this purpose the battery should be tested regularly once in from 100 to 200 miles. It is well also to test the battery in reserve at the same time, to see how fast it is losing its charge. The voltmeter used should also be tested occasionally by comparison with an instrument of known accuracy, else its reading is likely to be misleading.

20. In places where no direct current is available, but where alternating current can be obtained, storage batteries for ignition purposes or for use in electric vehicles may be charged through the use of what is known as a **mercury-vapor converter**, a comparatively simple device for converting alternating to direct current without using vibratory or rotating mechanism.

CARE OF STORAGE BATTERIES

21. The following are general directions for the care of ignition storage batteries: The electrolyte or acid solution should always cover the tops of the plates to a depth of about ¼ inch. Replace with fresh solution any loss by spilling, but use distilled water where the loss is due to evaporation. Use only chemically pure sulphuric acid. The proportion of acid to water is about 1 to 6, by liquid measure, at 66° F. Use a glazed-stone vessel for mixing, and *add the acid to the water very slowly*, while stirring with a glass or hard-

rubber rod, the purpose being to distribute evenly throughout the mixture the heat generated as the acid and water mix. The *water must never be poured into the acid*, for the reason that, being lighter than the acid, it would flow quickly over the top of the acid, and the rapid generation of heat would quickly transform the water into steam and cause both water and acid to be thrown violently from the containing vessel. When the electrolyte is cool, it should be tested with a hydrometer, such as that shown in Fig. 10, which shows a style of hydrometer designed for use in liquids heavier than water and one that is particularly adapted for use in testing the cells of automobile batteries. The hydrometer *a* is placed within the glass tube *b*, and by means of the rubber bulb sufficient electrolyte can be drawn up to float the hydrometer. Enough liquid is drawn up to fill the tube up to the mark *d* ground on the glass, and the reading is taken at the point where the floating tube *a* emerges from the liquid. On test, the hydrometer should read between 20° and 25° Baumé, or 1.162 to 1.2 specific gravity. When the battery is fully charged, the electrolyte should be about 30° Baumé or 1.26 specific gravity. If the specific gravity is low, remove some of the liquid with a rubber syringe bulb and add a stronger solution, not exceeding 1.4 specific gravity or 41° Baumé. If too high, add distilled water until the proper density is reached.

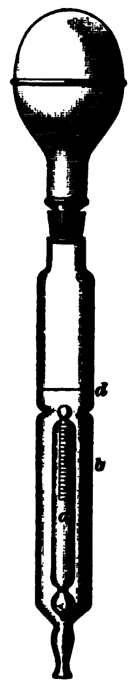


FIG. 10

When setting up new cells, pour through the holes in the cover, by using a funnel of glass or hard rubber, sufficient sulphuric-acid solution to cover the plates fully, and charge the battery *immediately*.

Whenever the battery is to be charged, remove the vent plug from each cell to allow the gas to escape. Care should be taken not to bring a naked flame near these openings while charging, as the gases given off are hydrogen and oxygen, and are highly explosive when mingled.

The completion of the charge is indicated, first, by a fine boiling or discharge of gas sometimes called *gassing*, which gives to the liquid a kind of milky color, and, second, by the voltage, which must be near to $2\frac{1}{2}$ volts per cell, the test being made during the charge. If a voltmeter or hydrometer is not available, the charge should be continued until each cell has been gassing, or bubbling, about 20 minutes. Do not prolong the charge beyond this limit. Cells should never be allowed to stand discharged, but when discharged should be recharged immediately.

22. Direct current only, never alternating, should be used for charging. Be sure to connect the positive wire of the charging line with the positive pole of the battery, as otherwise the battery may be ruined. If there is no voltmeter at hand to determine which wire is positive, attach a piece of lead to each wire, and immerse both in a small quantity of the electrolyte, but without allowing them to touch each other, when the positive piece will turn brown.

Always place sufficient resistance between the positive terminal of the charging line and the positive pole of the battery to make the voltage, as measured between the charging terminals, when the battery is connected, not more than 25 per cent. greater than the rated battery voltage, or 5 volts for a 4-volt, or two-cell battery.

23. The battery should be charged at a rate determined by its capacity in ampere-hours, the charging current, in amperes, being equal, for an ordinary battery, to the ampere-hour capacity divided by 10. Thus, a 65-ampere-hour battery should be charged at 6.5 amperes or an 80-ampere-hour battery at 8 amperes. Another and perhaps better rule is to charge at a rate not exceeding one-eighth or one-sixth of the ampere-hour capacity, and maintain this rate by gradually cutting out resistance until the voltage reaches 2.4 or 2.5 per cell, when the cells begin to gas; then cut down the charging current to one-twentieth of the ampere-hour capacity until the cells again gas freely, indicating a full charge.

If the battery is charged from an incandescent-light circuit, there must be used in series with the battery a resistance sufficient to absorb the greater portion of the voltage of the charging circuit. For this purpose a bank of lamps is generally employed. As the internal resistance of the battery is so small as to be almost negligible, it follows that a 100-volt lamp must be used for each 100 volts tension of the charging current, or a 110-volt lamp for a 110-volt current.

24. Wiring connections for charging storage batteries from direct-current lighting and power circuits are shown diagrammatically in Fig. 11 (*a*), (*b*), (*c*), and (*d*). Connections to a 110-volt lighting circuit are shown in Fig. 11 (*a*). A double-pole switch *a*, with fuses *b*, is connected between the mains and the battery as shown. In series with the battery *c* is a number of lamps, by means of which the charging current is limited to the proper amount. It is advisable to connect an ammeter *d* in circuit, though this is not absolutely necessary. The number of lamps required depends on the line voltage and on the charging rate of the cells. If the line pressure is 100 to 120 volts and but three or four cells are to be charged with a current of 5 amperes, then five 32-candlepower lamps requiring 1 ampere each, connected in multiple, as shown in Fig. 11 (*a*), will be sufficient. If 16-candlepower lamps requiring ½ ampere each are used, it will be necessary to connect ten in parallel. With a 220-volt circuit, there will be required twice as many lamps as with the 110-volt circuit, the second set of lamps being placed in series with the first. If the line pressure is 500 volts, it will be necessary to connect twenty-five 32-candlepower lamps in five rows of five lamps in series in each row, or fifty 16-candlepower lamps in ten rows, five lamps in series in each row as shown in Fig. 11 (*b*). In case it is convenient to charge at a lower rate, fewer rows of lamps will be needed, but the time for charging will be proportionately increased.

25. Lamps form a convenient resistance, as they are easily obtained, but an adjustable rheostat is frequently used,

as shown at r, Fig. 11 (c). The amount of resistance required in the rheostat can easily be obtained as follows: Let N be the number of cells to be charged in series, then $2N$ will be the approximate voltage for charging, since each cell may

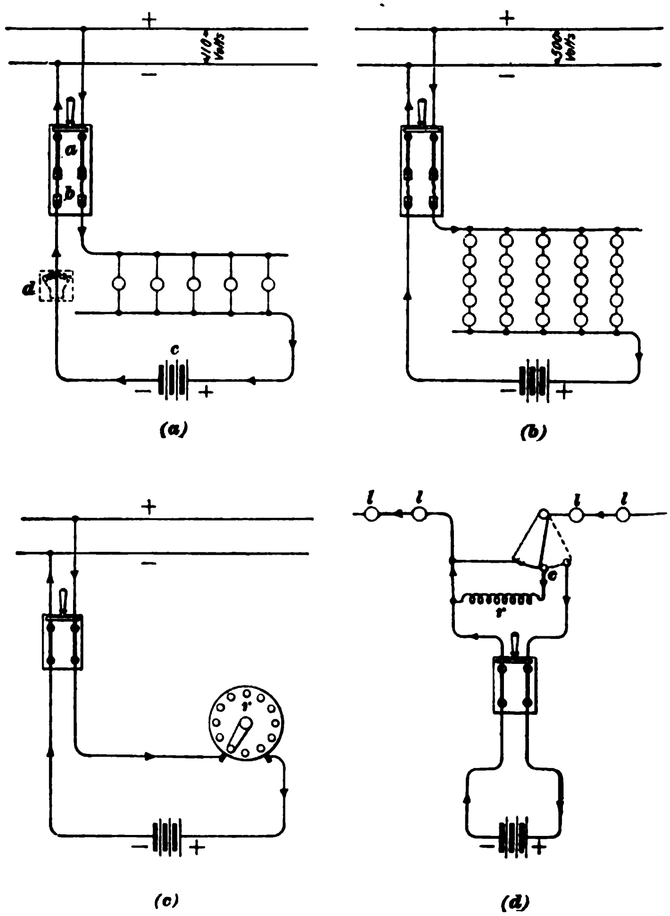


FIG. 11

be taken as requiring 2 volts at the beginning of the charge. If E is the line electromotive force, then $E-2N$ is the num-ber of volts effective in forcing current through the circuit because the electromotive force of the cells is opposed to the

of the line. If I is the charging current, then the resistance of the circuit will be

$$R = \frac{E - 2\,N}{I}$$

and this will be practically equal to the amount of resistance required in the rheostat, because the resistance of the cells is very low.

EXAMPLE.—Twenty storage cells are to be charged from a 220-volt circuit; how much resistance should be connected in series with them, if the charging current is to be 5 amperes?

SOLUTION.—Here $E = 220$, $N = 20$, and $I = 5$; hence, applying the formula,

$$R = \frac{220 - 2 \times 20}{5} = 36 \text{ ohms. Ans.}$$

This resistance should be adjustable, so that some of it can be cut out as the voltage of the cells increases, and it must be made of wire large enough to carry at least 5 amperes without overheating.

Charging with resistance in series is at best a makeshift, because it involves a large loss of energy; but in the case of small, portable batteries, this waste is not a very serious matter, especially as the use of the series resistance gives the most convenient and simple means of charging from existing circuits.

26. Sometimes cells are charged from constant-current arc-light circuits, but the practice is dangerous, and this source of charging current should never be used if any other is available. Constant-current arc-light dynamos generate a very high pressure, and, as arc-light lines are nearly always grounded to a greater or less extent, there is quite an element of danger in working around a battery that is being charged from such a source. Great care must be taken to see that the arc-light circuit is not opened when the battery is being switched on and off. This method of charging is shown in Fig. 11 (*d*), where *l*, *l* represent arc lamps. In this kind of circuit, the current is maintained at a constant value, usually from 6 to 10 amperes, so that when the battery is to be charged

it must be placed in series with the lamps. The battery is cut into circuit by means of a special switch, called a ***consumer's switch***, which is constructed so that it will neither open the circuit nor short-circuit the battery. This is done by means of a contact point c connected to a resistance r.

When the switch blade is moved to the dotted position, the resistance is first placed in series so that the line is not opened, and at the same time there is no short-circuiting of the battery. It will be noticed that, when the switch is in the dotted position, the resistance is in parallel with the battery, so that part of the main current is shunted around the battery. For example, the main current might be 9 amperes and the required charging current 5 amperes, in which case the resistance should be such that the difference between the two, i. e., 4 amperes, will flow through it. The pressure between the terminals of the resistance is equal to the electromotive force of the cells; hence, if I is the current shunted through the resistance, E the voltage of the series of cells, and R the resistance, then R is easily obtained from the relation

$$R = \frac{E}{I}.$$

27. When charging a battery from any source, especially when there is any doubt as to the direction of flow of the current, a test should be made to determine whether or not the positive plates are connected to the positive pole, so that the current flows in at this pole when the battery is charging. A simple method of doing this is to attach two wires to the mains, connect some resistance in series to limit the current, and dip the free ends into a glass of acidulated water, keeping the ends about 1 inch apart. The end from which bubbles of gas are given off most freely is connected to the negative main, so that the main to which the other end connects is the one to be attached to the positive pole of the battery. Another convenient method of testing the polarity is by means of a Weston voltmeter, or any instrument of similar type, which will give a deflection over the scale

only when the voltmeter terminal marked + is connected to the positive line.

The positive terminal of a storage battery is usually marked +, and is sometimes painted red. The positive terminals of the two cells commonly installed on automobiles and motor boats should be connected by separate wires to the two terminals of a double-throw switch located in an accessible position.

28. If a voltmeter or hydrometer test of a single cell of the battery shows it to be out of order, it should receive individual attention until it is restored to proper condition. If the density of the solution is incorrect, it should be altered as already indicated. If the voltage of one cell is low when the rest are charged, cut it out and recharge it separately. If the cell still fails to come up to the proper voltage, it is likely to be due to the presence of active material that has detached itself from the plates and fallen to the bottom, where it may have bridged the space between two plates, thus short-circuiting the cell. The novice had better not attempt to meddle with a battery in this condition, but with some electrical experience one may remove the pitch with which the top of the battery is sealed, and, taking off the hard-rubber cover beneath, lift out the battery plates and wash them in clean water.

The battery jar also should be emptied, cleaned out, fresh acid solution put in, and the plates put back in the acid as soon as possible. The battery may be sealed up again by melting the pitch and pouring it over the cover, taking care not to stop up the vent hole. If the battery terminals become dirty from acid creeping up on them, clean them with ammonia and a tooth brush. Ammonia may also be used to neutralize acid that may be spilled or that may get on the clothes or fingers, but to be effective it must be applied immediately.

29. When the battery is not to be used for some time, it may be laid up by one of the two following procedures,

which are those recommended by the National Battery Company for their cells, and are equally applicable to others.

First Method.—When, for any reason, a battery is not to be used for some length of time, it may be kept in good condition by giving it an occasional freshening charge. This charge should be given at intervals not greater than 2 months, and preferably once in every 6 weeks. The freshening charge should be at the rate of one-twentieth of the ampere-hour capacity of the battery, and should be continued until the battery gases freely. This is by far the simplest and the best way to take care of a battery when it is not in actual service, as it will always be ready for immediate service when needed. When a battery cared for in this manner is again placed in service, the additional precaution may be taken to give it the three-quarter discharge and the charge following, to insure the full capacity, as described in the second method.

Second Method.—If a battery is not to be used for some time, and cannot receive an occasional charge to keep it in good condition, it should be put in dry storage. To put a battery in dry storage, it should first be fully charged and given an overcharge; then the electrolyte should be emptied out and the cells allowed to stand until the negative plates begin to steam, which will be within about half an hour.

The next step is to cool the plates. Fill the cells with distilled water, and allow them to stand for about 10 minutes; then pour out the water, and again allow them to stand until the negative plates steam quite freely. This operation should be repeated until the plates lose their heat.

Next put in the acid solution that was removed, and allow the cells to stand for 1 hour, after which again remove the solution and put the battery away in a dry place where the temperature will not get below the freezing point.

After the last process, in which the plates are allowed to soak in the acid solution for 1 hour, they should be watched for a day to see that they do not again become heated. Should it be found that they are heating, the acid-soaking process should be repeated until there are no more signs of heat.

While the plates are still drying, it is possible that nightfall may come on. The condition of the plates may still be such as to make it inadvisable to leave them. If inconvenient or impossible to continue the above process during the night, fill the cells with acid and allow them to stand until morning, when the process may be continued.

30. To put these cells again into commission, fill them with an acid solution having a specific gravity of 1.21, free from impurities, and charge at the minimum rate as stamped on the name plate until fully charged. This will require about 40 hours. During this time, the battery should be watched closely, and the temperature of the acid taken occasionally. If the temperature should get above 100° F., the charging current should be cut off for a few hours and the cells allowed to cool; then the charge should be continued at the minimum rate until the cells have been charged for 40 hours. It would then be strongly advisable, in order to insure the full capacity of the plates, to give the cells about a three-quarter discharge; then charge them again as before until they gas freely, when the battery will be ready for service.

The simplest way to secure a three-quarter discharge, where the battery is being charged through a lamp circuit, is to reverse the connections of the battery, that is, connect the negative charging wire to the positive terminal of the battery and the positive charging wire to the negative terminal, and allow the battery to discharge until the voltage has fallen to about one-quarter that at full charge.

This discharge should be conducted at a rate of one-tenth the capacity of the battery. If, for example, the capacity of the battery is 40 ampere-hours, this discharge should be carried on at a 4-ampere rate for a period of about 7 hours. The battery connections should then again be reversed, and a charge carried on at the minimum rate until the battery gases freely. It is better not to make a practice of recharging storage batteries when they are less than half discharged.

SPARK COILS

CONSTRUCTION AND OPERATION

31. In their application to the marine engine, **spark coils** are broadly divided into two classes: the ordinary inductance coil using the primary current only, and the double-wound jump-spark induction or Ruhmkorff coil, in which a secondary current of high potential is induced and strengthened by means of a condenser, usually placed within the coil box, or a condenser is provided for each coil; sometimes the circuit is so arranged that one condenser may be used with several coils.

Induction coils are of various shapes and types, and ordinarily are from 6 to 10 inches in length, rarely longer, and their construction and operation are so well known as to need no extended description here. They should be kept as dry as possible, even though they are usually protected from dampness by means of paraffin wax, shellac, or similar substances.

32. Coils used in high-tension or jump-spark ignition are of two general classes, one with a vibrator that opens and closes the secondary circuit and is actuated by the electromagnetism of the iron core of the coil, and the other with no vibrator. The former gives a rapid succession of sparks, and is the type used for the most part in jump-spark ignition; while the other, which is rarely met in marine practice, gives a single large spark on breaking the circuit. This latter type is used for the most part in motor-cycle work where minimum weight is essential.

The object of primary ignition will be referred to later in connection with magneto-generators, with which it is principally used. Where batteries are used, the jump-spark system is almost invariably employed.

33. Fig. 12 shows the appearance of a typical jump-spark coil for one cylinder. It is a standard four-terminal

coil, in which the binding posts *a* and *b* are, respectively, the positive and negative of the secondary coil, and the binding posts *c* and *d* connect, respectively, to the engine frame and the battery. Posts *b* and *c* may be connected

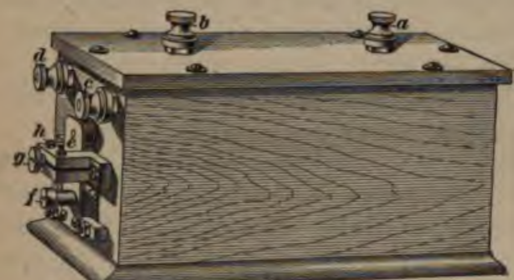


FIG. 12

together, since both are grounded. The flat vibrator or trembler spring *e* is adjusted with respect to its tension by the screw *f*, and *g* is the customary platinum-tipped contact screw against which the vibrator works.

In Fig. 13 are shown the connections to a coil of this type.

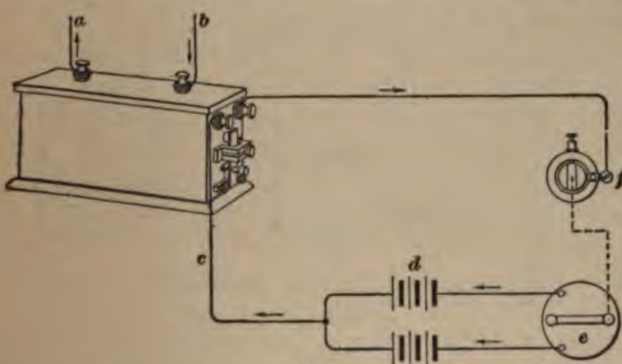


FIG. 13

The secondary, or spark-plug, terminals are shown at *a* and *b*, the current flowing from *a* to the insulated electrode of the plug, returning from the grounded electrode of the plug to the grounded terminal *b*, which may be connected

to the negative terminal of the primary winding of the coil. Through the wire *c*, current flows to the coil from the battery *d*, when the switch *e* is closed and the insulated member of the timer *f* is in contact with the grounded member of the timer, the direction of the current being indicated by the arrows. The switch may be placed either between the negative terminals of the battery and the timer, as shown, or between the primary terminals and the coil.

34. In Fig. 14 are shown, diagrammatically, the connections of the coil shown in Fig. 12, the switch this time being located between the batteries and the coil. Two batteries

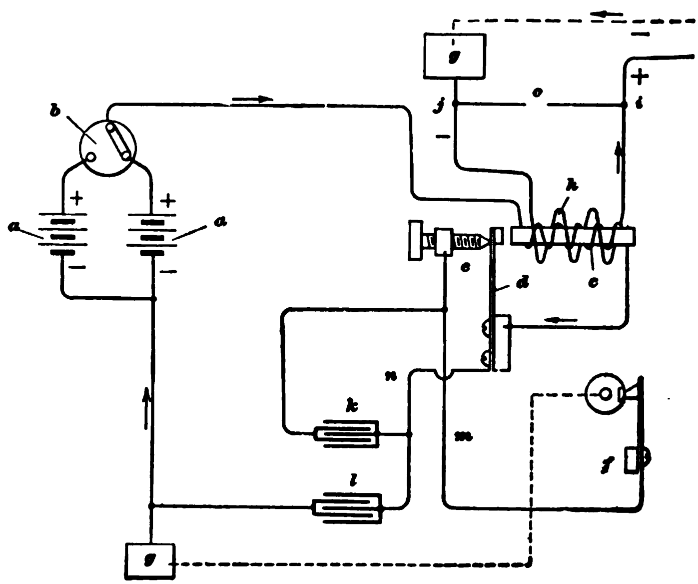


FIG. 14

a, *a* are shown, either of which may be used by turning the switch *b*. The passage of the current is through one or the other of the batteries *a*, *a*, through the switch *b*, primary winding *c*, vibrator *d*, contact screw *e*, insulated member of the timer *f*, and finally into the engine frame, as indicated by the ground *g*, from which it returns to the negative

minal of the battery. The secondary winding is shown *h*. As the secondary current is induced on rupture of : primary, its direction is the same as that of the primary, ich makes terminal *i* the positive. The negative termi- *j* of the secondary winding is shown with an independ- : ground connection *g*, but it might equally well be con- :ted to the primary winding, in which case the current uld return to it through the battery and switch. This 'ticular coil has two condensers: the regular condenser *k*, ich is found on all jump-spark coils, and which absorbs extra or self-induced primary current at the moment of)ture; and another condenser *l*, which comes into play in e the engine speed outruns the speed of the vibrator, and latter *sticks*—that is, refuses to work fast enough to 'p time with the engine. If this occurs, the only rupture hat taking place at the timer, and the extra current then s to the condenser *l* by way of the ground *g* on the ine frame, and the wires *m* and *n*, there being then no ak at the vibrator.

5. The feature discussed in the last article is not found all coils, but it is useful with a high-speed engine, as :t coil vibrators, on account of their inertia, do not work ıbly at engine speeds exceeding 1,200 to 1,400 revolu- s per minute. Of course, the rupture at the timer ırs somewhat later than at the vibrator, since the latter ırs soon after the timer makes contact; and, therefore, he critical point when the vibrator begins to stick, the er will need to be advanced in order to get the same rk time. With a little practice, the operator learns to)gnize the point to which the timer must be advanced. *o* is shown a *safety spark gap*, as it is called, which is pro- ed inside the case of all spark coils to prevent overstrain- of the insulation, in case an abnormally severe current is t through the coil. This gap is provided with a pair of es soldered to the bottom ends of the binding posts *a* and 'ig. 12, and is about ½ inch long, that being equal to the atest air gap that the spark is ordinarily required to

jump. This is equivalent to about $\frac{1}{16}$ inch under average compression.

36. Every spark coil requires occasional attention to the contact points of the trembler, as these become worn and pitted under the large currents often employed. Special means are commonly used to prevent the adjusting screws of the trembler from working loose. In the coil shown in Fig. 12, these means take the form of clamp screws *h*, by which the split yoke in which the contact screw *g* is threaded may be drawn tight on the screw. As the adjustment must be very accurate, and the vibration of the trembler quickly brings to light any looseness, some such provision as this is very necessary.

37. A special form of trembler, found on some French coils, is shown in Fig. 15. For comparison, Fig. 16 shows

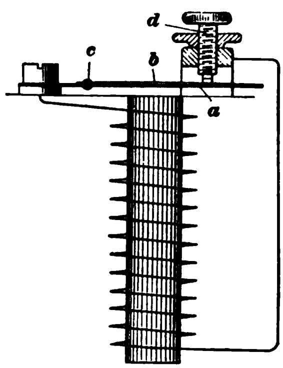


FIG. 15

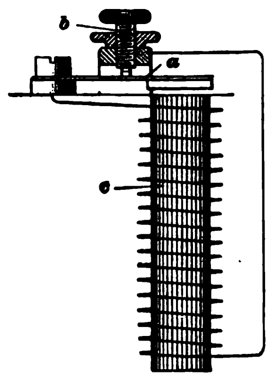


FIG. 16

the hammer trembler of the ordinary coil. It will be noticed that, in the latter, contact between the trembler spring *a* and the screw *b* is broken almost instantly when the hammer begins to move, the only delay, after the hammer is in motion, being that required to allow the current to build up in the coil, and to allow the hammer head to travel as far as the yield of the spring will allow before the rebound of the spring carries it toward the core *c*. As the hammer head is quite heavy, it is evident that there is a

limit to the speed of the vibrator, due largely to the inertia of the head. The trembler shown in Fig. 15, on the other hand, consists of a pair of flat steel blades, which, while not so hard as to retain much permanent magnetism, are still hard enough to act efficiently as springs. The lower spring *a* is supported in the usual manner, and the upper spring *b* is riveted to it at the point *c*. Normally, the blades separate slightly, and the upper one makes contact with the screw *d*. Consequently, when the circuit is closed, the lower blade *a* is first attracted, and it moves downwards; while the upper one, by virtue of the initial spread between the blades, remains in contact with the screw. When, however, this spread has been fully taken up, the upper blade is pulled out of contact by the continuing motion of *a*; and, as *a* has by this time acquired a considerable velocity, the separation between *b* and *d* is very abrupt, thus causing an energetic excitation of current in the secondary coil. By reason of the extreme lightness of these springs, and because of the fact that contact is maintained for a considerable fraction of the working period of the trembler, the speed is exceedingly high, without sacrifice of efficiency, and without preventing the magnetism from adequately building up between breaks.

CARE OF SPARK COILS

38. The care of the spark coil is limited to seeing that the vibrators are kept clean and properly adjusted. The platinum points of the contact screw should be kept flat and clean, and to this end the contact screw should occasionally be taken out, and both contacts dressed with a fine file. If the adjustment of the contact screw against the spring is too tight or too loose, the operation of the coil will be erratic, and in the former case the demand for current will be excessive.

39. Most coil vibrators now made have two adjustments: one for spring tension, involving also the distance

of the vibrator head, or armature, from the core, and one for the pressure of the contact points. As there are so many varieties of coil, an exact rule for their adjustment can hardly be laid down; but it may be said in general that the armature should be as close to the core of the coil as is consistent with clearance to insure that it cannot touch the latter. The spring should be stiff enough to insure rapid vibration, but not so stiff that a considerable current is required to attract the armature; and the contact screw should bear with a light pressure, to permit the use of a small current, but not so lightly as to make the vibrator sluggish. The faster the vibrator works and the smaller the interval between sparks, the smaller will be the angle through which the engine crank will turn in that interval, and the more uniform will be the spark time from one cycle to the next.

The best procedure in adjusting is, first, to run the contact screw back until it is out of contact; then, to adjust the spring until the armature is from $\frac{1}{16}$ to $\frac{3}{32}$ inch from the core —the lighter and more rapid it is, the closer it can be adjusted—and, finally, to run down the contact screw until a clear and high, but not a tinny, note is produced when the circuit is closed. Then connect an ammeter in the primary circuit, and note the reading when the engine is standing still and the vibrator working. It should read from .25 to .5 ampere, for a moderate-compression motor; but, if the compression is high, from .5 to 1 ampere may be required. By adjusting the spring slightly, the current can be reduced without making the vibrator work slower. When the minimum current has been found, note whether the engine develops its full power when it is running. If not, try turning the contact screw down a little more; but do not leave it down unless it improves the power, as it simply wastes current.

40. If the engine has more than one cylinder, tune the vibrators separately and as nearly alike as possible. When a coil is supplied with the engine, it is well to note its

sound and adjustment when the engine is received from the factory, and to restore this sound as nearly as possible when the coil requires attention.

A weak battery will need a vibrator adjustment different from that for a fresh battery, the contact screw bearing with a lighter pressure and the vibrator speed being necessarily somewhat slower.

Occasionally, it will happen that the insulation of the secondary winding on the coil will break down, which will cause the coil to give a weak spark or none at all, even if the battery is fresh and the vibrator adjustment good. Sometimes, also, the wires leading to the condenser break. This results in excessive sparking at the vibrator and timer.

SPARK PLUGS

TYPES OF PLUGS

41. The chief difficulty experienced in connection with the jump-spark system of ignition is found in maintaining proper insulation of the secondary circuit. On account of the carbon gradually deposited over the interior of the combustion chamber from the fuel and the slowly-burning cylinder oil, it follows that the most difficult place in the secondary circuit to keep properly insulated is the point where the spark is produced. The problem of insulation here has been solved by the use of the **spark plug,** a section of a representative type of which is shown in Fig. 17 (*a*). A spark plug consists of a steel shell *a* that screws into a threaded hole in the wall of the combustion chamber; a porcelain or mica insulator *b*, and a threaded bushing *c*, by the aid of which, with suitable packings *d*, the porcelain is made air-tight in the shell; and a metal stem *e*, made air-tight by packing or cement, according to its form. The secondary current is conveyed from the positive terminal of the coil to the binding post *f*, at the end of the stem *e* by an

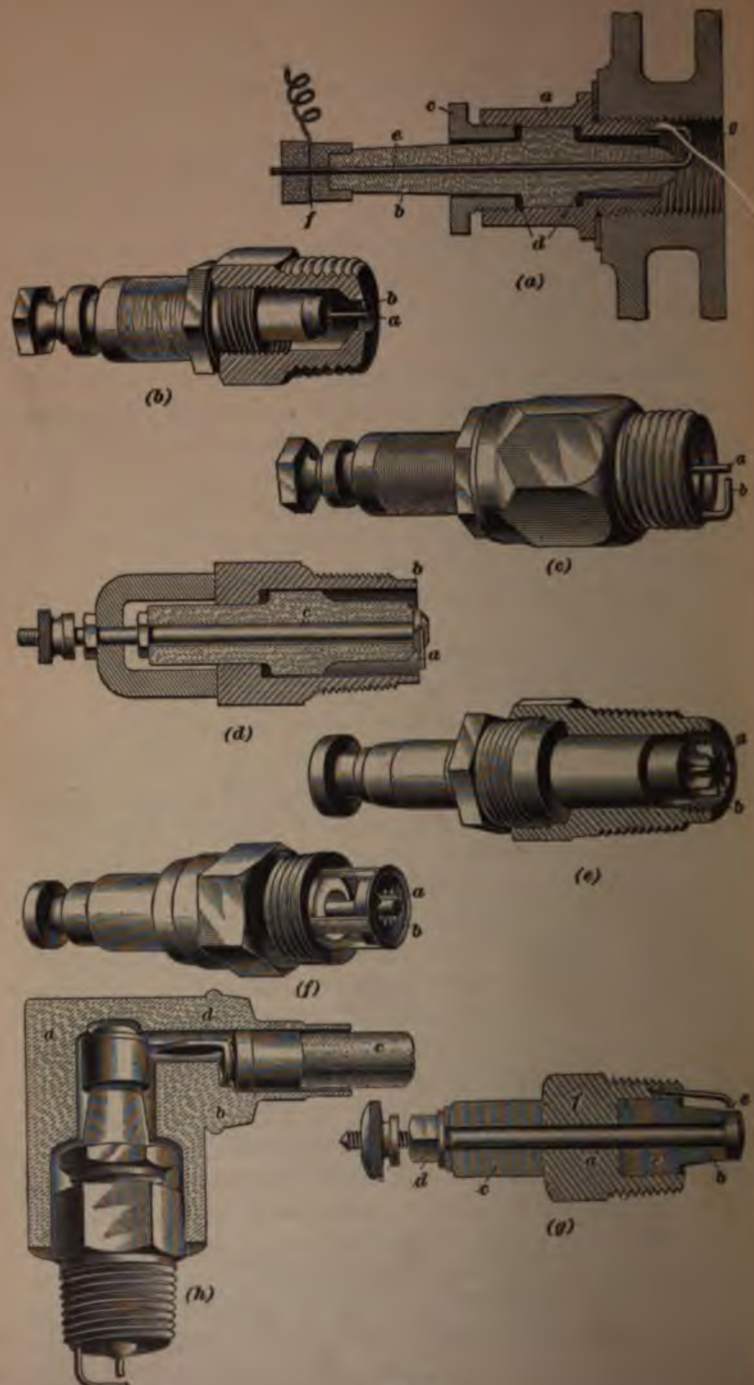


FIG. 17

insulated cable, and the spark jumps from *e* to a projecting point *g* connected to the shell *a*. From the shell, the secondary current goes through the engine frame back to the negative terminal of the secondary winding, which, like the battery, is grounded on the engine. By detaching the cable from *f*, the plug may quickly be unscrewed for inspection and cleaning of the porcelain.

The construction of the plugs shown in Fig. 17 (*b*), (*c*), (*d*), (*e*), and (*f*) is but little different from that shown in (*a*). What is known as a closed-end plug is shown in (*b*), the points *a* and *b* being located in the nearly closed end of the plug. The point *a* is concentric with the plug-end opening into which the point *b* projects from one side. The so-called open type of the same plug is shown in (*c*), the point *a* projecting beyond the end of the plug, as shown. The point *b* can be turned away from *a* to increase the gap between the points. In the plug (*d*) the point *a* is mounted in the hexagonal head *b* of the insulated bolt *c* for conducting the current and for keeping the plug tight, the spark bridging the gap between the point *a* and the threaded shank of the plug. In the plug (*e*), the insulated electrode *a* resembles a star. The spark occurs between the projections of the insulated electrode *a* and the threads of the grounded electrode *b*. In the plug (*f*), the insulated electrode is threaded and the opening *b* of the grounded electrode is star shaped. In the plug (*g*), the insulated electrode *a* is wrapped with sheet mica *b*, and then surrounded with mica washers *c* pressed closely together under heavy pressure and held in place by a brass nut *d* and washer. The grounded electrode *e* is fastened in the bushing *f*. Spark plugs are sometimes protected against the short-circuiting effect of moisture by means of a porcelain hood or cap *a*, Fig. 17 (*h*), having a recessed neck *b* on one side to receive the wire *c*, which is connected to the plug by a terminal link *d* in the manner shown.

42. While there are a great variety of spark plugs on the market, each with some special features of advantage that

may or may not be possessed by others, the chief requirements of a good spark plug are the following:

1. The insulating material of porcelain or mica between the central electrode or stem, which is connected to the positive terminal of the coil, must not be too easily coated with carbon deposit, where exposed to burning gas and oil vapors. It is to be remembered that the electrical resistance of any gas increases considerably as the gas is compressed, so that, although the current may jump between the proper spark points when the plug is in the open air, it may find the resistance between these points too great when the plug is in the cylinder and the charge is compressed, and will take an easier path through the carbon coating on the porcelain. Practically the same thing will invariably happen if the porcelain is cracked, for the same reason, namely, that the current will take the direct route through the crack rather than the difficult route from spark point to spark point through the compressed gas. The leakage through the carbon deposit is made as difficult as possible by giving the leaking current a considerable distance to travel, and there are also special devices sometimes employed to prevent the collection of carbon.

2. The plug must be easily cleaned of whatever carbon may be deposited on it. To clean the plug properly, it must be taken apart, and it must not be too difficult to reassemble the parts and make the plug gas-tight, nor must the packing process endanger the porcelain more than necessary.

3. The plug must fit the standard sizes of threaded spark-plug holes, and must not be unduly expensive to replace. Among the sizes most used is the so-called metric size, the proportions of which are based on the metric system of measurement. Most of the imported spark plugs are of this size, which is approximately the size of a $\frac{3}{8}$-inch pipe tap, but is not tapered. American spark plugs are either of the $\frac{1}{2}$-inch or the $\frac{3}{4}$-inch pipe sizes. The pipe sizes are tapered, and depend for tightness on the plug being screwed in tightly. This method is not altogether

satisfactory, as the thread in the engine wears and permits leakage, which causes the plug to heat; and both the engine and plug tapers are liable to variations that may make one plug screw well into its hole while another catches only a few threads, and consequently is not so well placed for prompt communication of flame to the compressed charge. Plugs that are not provided with tapered threads are made gas-tight by gaskets of asbestos covered with thin copper sheathing.

43. It is desirable, though not essential, that the spark points should be of platinum, since when made of this metal they do not burn away to any appreciable extent. When not made of platinum, they are often made of a special alloy of steel and nickel, which resists oxidation nearly as well as platinum. The air gap between the spark-plug points should not exceed $\frac{1}{32}$ inch, nor be less than $\frac{1}{64}$ inch; the best size is about midway between these dimensions. In case a battery gives out and there is no other at hand, the car may be kept going for a short distance by pinching the spark-plug points a little closer together, to reduce the resistance offered by the gap.

AUXILIARY SPARK GAP

44. A plug whose porcelain is slightly covered with soot can be kept in action by the use of an **auxiliary spark-gap** device, two forms of which are shown in Fig. 18 (*a*) and (*b*). This device consists simply of two insulated terminals *a* and *b* with points separated by an adjustable gap, usually about one-sixteenth inch in length. In the form shown in Fig. 18 (*a*), the terminals are enclosed in a glass tube *c* to prevent possible ignition of stray gasoline vapor. This form is connected in the secondary circuit by means of the connecting screws *d* and *e*. The form shown in Fig. 18 (*b*) is attached to the binding post of the spark plug itself, and the spark jumps from the point *a* to the binding post *b*. The base *f* is made of fiber.

When the primary circuit is broken by the timer, it

requires a short time for the induced current in the secondary circuit to build up to its full voltage; and, in order that the full voltage may be reached, it is necessary that the first small quantity of energy induced in the secondary shall not be allowed to escape. If the spark-plug insulation is not perfect, or if the plug is sooted, the charge first induced leaks away either through the insulation or over the soot deposit, and the voltage does not become great enough to force the current across the gap and produce a spark. By the use of an auxiliary spark gap outside the cylinder, the

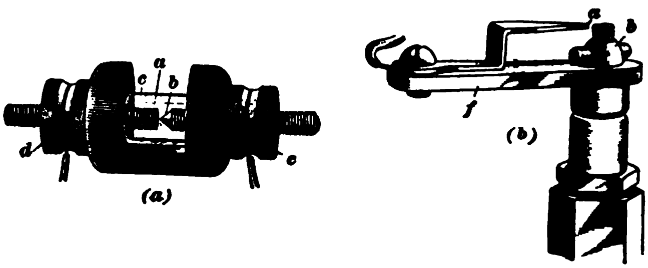


Fig. 18

secondary circuit is held open, this leakage is prevented, and the induced current builds up to its proper voltage, so that, when the gap is finally bridged, the entire energy of the induced charge is employed in producing the spark. With the recent improvements in plugs, and by proper attention to the carbureter adjustment and to lubrication, sooting of plugs is avoided to a greater extent than it used to be, but there are many occasions when the auxiliary spark gap is exceedingly useful.

TIMERS AND DISTRIBUTORS

CONSTRUCTION AND OPERATION

45. Timers, or primary commutators, as they are commonly called, are devices whose object it is to close the ignition circuit at some prearranged point or points in the revolution of the crank-shaft, keeping it closed sufficiently long to insure ignition, and then opening it, no matter whether the engine is of the single or the multi-cylinder type. The principle of operation of all timers is practically the same, but the length of the time of contact varies, and in some cases an extremely short life of the battery is the result. Some timers, especially those on cheap two-stroke marine engines, are arranged on the engine crank-shaft, unprotected by a cover, with nothing whatever to prevent any gasoline vapor in the lower part of the boat from taking fire, as there is always a spark or small arc at the time of breaking the contact.

46. It might be supposed that a multi-cylinder engine would be regularly equipped with a single spark coil, whose primary circuit would be closed as many times in each cycle of the engine as there were cylinders to be sparked, and whose secondary current would be led by a commutating device to the cylinder desired. This is, in fact, done in some recent cases; but the difficulty found until lately in confining the high-tension secondary has led the majority of builders to prefer commutating the primary, and using a separate spark coil for each cylinder.

47. In Fig. 19 is shown one form of timer, partly in section, and Fig. 20 shows it wired for connection to the engine. The case consists of a large fiber disk *a*, with a thick raised rim *b*, in which are embedded four brass contact pieces *c*, each connected to its proper coil. The shaft runs through the disk *a*, which has a bearing on the shaft, and carries a

hub *d* and pivoted lever *e*, on one end of which is a roller *f* that runs against the internal ring *b* and makes contact with the insulated segments *c*. A spring *g* connected to the other end insures good contact. A rod connecting the arm *h* with a lever provided for the purpose of advancing the spark and called the ***spark advance lever***, holds the disk *a* from rotating with the shaft and determines its position. This

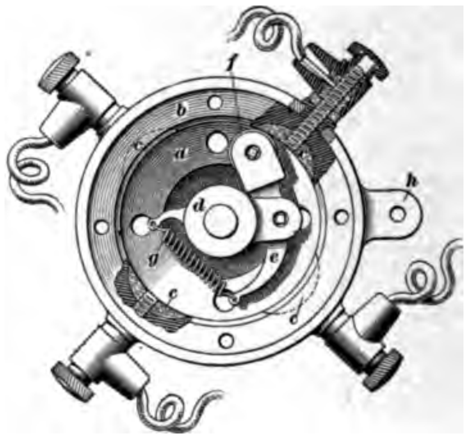


FIG. 19

sort of timer is arranged to be oiled freely, and the oil does not interfere with its working. The arrangement shown in Fig. 20 includes a button *a* on the steering wheel of an automobile, by which the current may be temporarily interrupted at the will of the operator. This is sometimes convenient when coasting, or in managing the machine when surrounded by other vehicles. Two pair of storage cells in their cases are represented by *b* and *c*. Current from the storage batteries passes to the primary windings of the coils in the coil box *d*, the current induced in the secondary windings of the coils passing to each of the spark plugs in turn when the proper contact at the timer is made.

48. Because of the arrangement of the cranks, and in order to take advantage of the alternate movements of the pistons, the **order of explosions** in the several cylinders

must be either 1-2-4-3 or 1-3-4-2, these numbers corresponding to the numbering of the cylinders as shown in Fig. 20, where the order of firing is 1-2-4-3. If the purchaser of an automobile or motor boat is not sure as to the order of firing of his engine, he can easily determine what it is by turning the

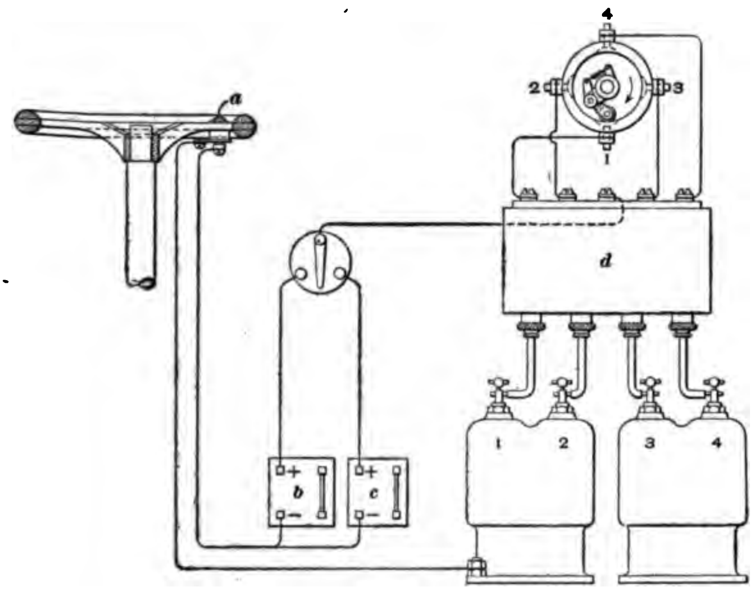


FIG. 20

engine slowly and watching the order in which the exhaust valves open, which will indicate the order in which the charges in the cylinders must be ignited.

49. That the order of firing must be as just indicated will be apparent by referring to Fig. 21, which is a diagrammatic illustration of a vertical four-cylinder four-cycle engine showing the relative positions of the pistons. The arrangement of the crank-shaft is such that, while the pistons in cylinders 1 and 4 are descending on their working and suction strokes, respectively, the pistons in cylinders 2 and 3 are moving upwards on their compression and exhaust strokes. Representing the working, exhaust, suction, and compression

strokes necessary to complete a cycle by the letters *W*, *E*, *S*, and *C*, the following diagrams, Fig. 22 (*a*) and (*b*) serve to illustrate how the movement of the exhaust valves makes it possible to determine the order of firing, which is dependent on the operative relations between cylinders 2 and 3; that is to say, whether the compression or the exhaust stroke is to take place in cylinder No. 2 or in cylinder No. 3 when the order of events in cylinders No. 1 and No. 4 are as indicated. At the top of the diagrams, Fig. 22 (*a*) and (*b*) the numbers of the cylinders corresponding to the numbering in Fig. 21 are given, the arrows just below the numbers indicating the initial direction of movement of the pistons; while the figures at the left indicate the number of degrees of travel of the cranks necessary to carry the pistons to the beginning of the strokes repre-

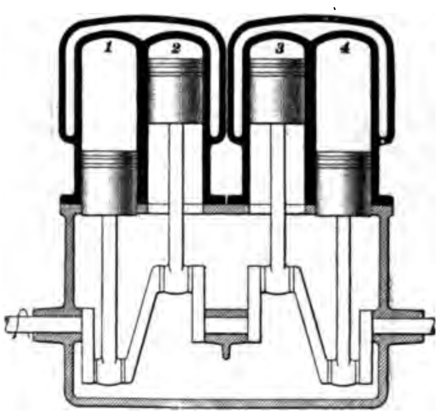


FIG. 21

	1	2	3	4
	↓	↑	↑	↓
0°	*W*	*C*	*E*	*S*
180°	*E*	*W*	*S*	*C*
360°	*S*	*E*	*C*	*W*
540°	*C*	*S*	*W*	*E*
720°	*W*	*C*	*E*	*S*

(*a*)

	1	2	3	4
	↓	↑	↑	↓
0°	*W*	*E*	*C*	*S*
180°	*E*	*S*	*W*	*C*
360°	*S*	*C*	*E*	*W*
540°	*C*	*W*	*S*	*E*
720°	*W*	*E*	*C*	*S*

(*b*)

FIG. 22

sented by the letters *W*, *E*, *S*, and *C*, the beginning of the working stroke, or point at which the charge is fired in cylinder No. 1, being taken as zero.

50. To complete a cycle in any one cylinder, the crank must travel 720°, or two revolutions; but, since there are four cylinders, the crank-shaft receives four power impulses during two revolutions, and hence, in order that the application of power may be uniform, the impulses must occur 180° apart. Fig. 22 (*a*) shows that, when the working stroke in cylinder No. 2 begins at 180°, it will be necessary to fire the charge in cylinder No. 4 at 360°, following with cylinder No. 3 at 540°, the cycle being completed just at the point where an explosion is about to take place in cylinder No. 1 at 720°, or two complete revolutions. With this arrangement, the order of firing is shown to be 1–2–4–3. Fig. 22 (*b*), however, shows that, when the second power impulse takes place at 180° in cylinder No. 3, the order of firing must be 1–3–4–2.

51. Timers should be oiled and cleaned regularly, but beyond this they require little attention. Like any other part subject to friction and sparking, the timer will gradually wear out and will require such attention and repair as its condition and construction may make necessary.

DISTRIBUTORS

52. It was once thought impossible to insulate the secondary circuits of a jump-spark system so thoroughly that a single coil could be used to advantage for a multiple cylinder engine, in connection with a **secondary commutator** or **distributor,** to deliver current to more than one spark plug. Lately, however, this has been accomplished successfully, one method being illustrated in Fig. 23, which is a diagrammatic view showing the arrangement of the wiring for a four-cylinder engine. From the battery *a*, the current passes through the switch *b* and the primary winding of the induction or spark coil *c* to a binding post *d* connected with the insulated contact member of the timer *e*. On the cam-shaft, or any other convenient shaft that turns at one-half the speed of the engine, is a four-lobed cam *f* that makes contact

with the insulated member four times in each revo: the primary current being completed through the unins cam *f*, engine, frame, and ground connection at *g*.

The spark coil generally has the usual vibrator, but times the single spark produced by breaking the cir the timer is considered sufficient. The induced cur led from the positive terminal *h* of the secondary coil

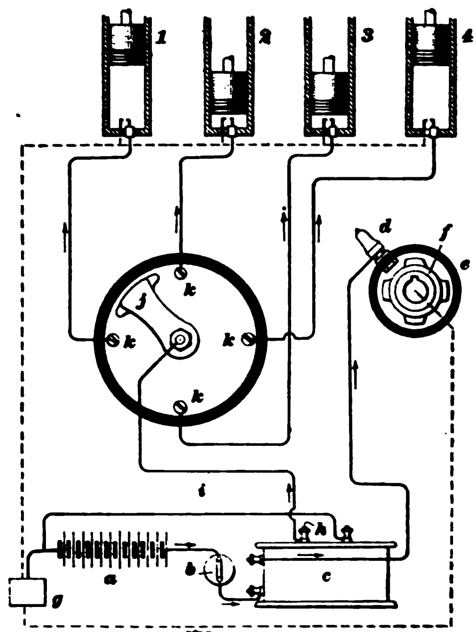


FIG. 23

heavily insulated cable *i*, to an insulated revolving whose end passes over four insulated segments or heads *k*, *k*, connected to the spark plugs as shown. arm *j* may or may not actually touch the points *k*, *k*, it does not, the spark will readily jump the gap if the is small. The whole is suitably encased to e: moisture. The important point in a successful distrib to have very good insulation. Hard rubber is the insu material commonly used, and all electrically active parts are placed as far apart as possible.

53. Commonly, the distributor is mounted on the same shaft as the timer. Fig. 24 shows this arrangement in section and elevation. The primary contact is made by a steel ball *a*, held in place by a spring as shown. The sleeve *b* and contact cam *c* are carried on a shaft turning at one-half the speed of the engine. The secondary current is led to the binding post *d*, through which it travels by way of the contact ball *e* to the brass strip *f* that runs over the hard-rubber surface *g*, and makes contact with the flat-headed screws *h*, *h* embedded therein. These screws carry the current to the several spark plugs. Efficient insulation between the primary and the secondary is secured by the long, hard-rubber stem *i* on which *f* is carried. The casing *j* is rotated for advance or retardation of the spark by the arm *k*. It is evident that the movement of this arm advances or retards both primary and secondary contacts alike. A ball bearing *l* is shown, which is sufficient to support *j*, as the latter carries little weight.

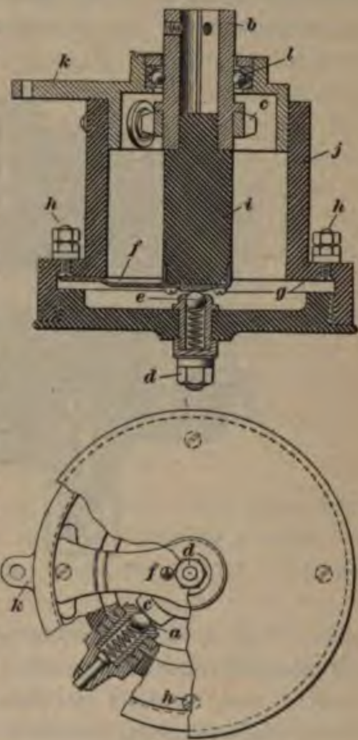


FIG. 24

54. In the combined timer and distributor shown in Fig. 25, the shaft *a* carries at its extreme end the timer cam *b*, which has as many lobes as there are spark plugs to be supplied. These lobes successively make contact with the steel plunger *c*. This plunger is supported in a hard-rubber casing *d*, and by means of a sleeve is fastened on *a* for rotation according to the spark advance required. Attached

to *a* by a taper pin is a hard-rubber barrel *e*, carrying a
tact ring *f* extending clear around it and connected thr
a longitudinal strip with a single contact segment nea
left-hand end of *e*. The secondary current is carried t
ring *f* by the contact plunger *g*, and four other plu
mounted in *d* make contact successively with the seg
connected with *f*. The hard-rubber mounting affords
cient insulation. To the right-hand end of *d* is screw

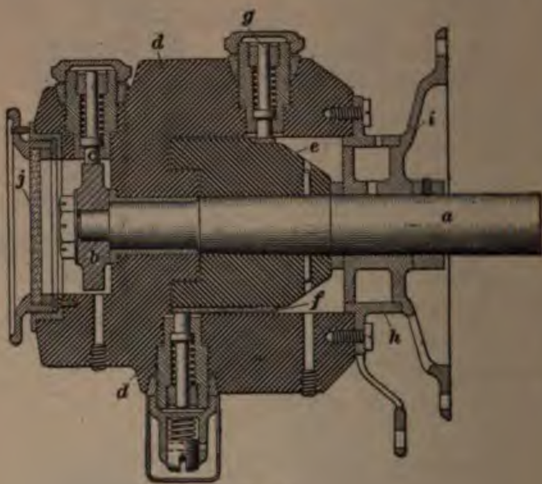


FIG. 25

metal ring *h*, from which projects an arm for rotating
advance or retard the spark. The light casting *i* affor
bearing for the shaft and for *h*, and can be screwed to
convenient support, the shaft *a* being operated by a cha
flexible shaft driven from the cam-shaft. A glass fro
through which the action of the timing cam may be watc
is provided.

IGNITION GENERATORS AND MAGNETOS

GENERATORS

55. Owing to the fact that the ignition circuit of a four-cylinder engine is closed twice in each revolution, there is a great consumption of battery power; and, in order to escape the annoyances of frequent recharging of storage batteries or replacement of primary cells, various forms of mechanically operated current generators are often employed. The simplest of these in some respects is a miniature dynamo, taking the place of a battery, with little or no change in the coils and wiring. It is generally used in conjunction with jump-spark coils, but if employed with primary-spark apparatus no coil is required, as the self-induction of the armature furnishes the extra current for ignition. Dynamos for this purpose are commonly of the iron-clad type to exclude water and protect the field windings, and the armatures have a number of coils so that the generators give a practically constant current.

56. Generators used for ignition are sometimes employed for furnishing light and for charging storage batteries, the ignition system being so arranged that the excess current generated when igniting the charges in the engine is used in charging the storage batteries, which in turn supply current for starting the engine or furnish current for a limited number of small incandescent lights.

The difference between a dynamo and a magneto is that the dynamo consists of an armature rotated through a field composed of electromagnets, while in the magneto the field is a permanent magnet. The magneto can be run in either direction, while the dynamo as usually constructed for the purpose can be run in one only, as to run in both directions would necessitate double sets of brushes.

Low-tension magnetos are used for marine gas-engine ignition, but only with the make-and-break system, because

magnetos, as usually constructed, generate alternating current, and the inductance coils commonly employed with the primary ignition system can be operated only by means of direct current from a dynamo.

57. Dynamo-electric ignition generators require very little attention beyond occasional oiling, polishing of the commutator with a piece of fine sandpaper, and trimming the brushes. They are, however, rather bulky and quite heavy, and their efficiency per pound is much below that of special types of magneto-generators. When the motor is turned by hand, the speed of the dynamo is commonly too slow to generate a good spark, and it is necessary to use a dry or storage battery for starting, and to switch to the dynamo afterwards. If, as is usually the case, the dynamo generates a more powerful current than the battery gives, this arrangement has the slight drawback that the coil vibrators do not generally work equally well with both currents, and frequent adjustment is required.

58. It is quite feasible to use the dynamo simply to charge a storage battery, the current for the coils being taken from the latter, the speed of the dynamo being just high enough to make sure that the battery will not discharge through the dynamo against the voltage of the latter. The positive terminal of the dynamo is then connected through an automatic switch with the positive of the battery, and the negatives of the dynamo and battery are connected direct. The rest of the ignition circuit is the same as usual. The switch, which is worked automatically by an electromagnet in the dynamo circuit, breaks the charging connection when, through the slowing down or stopping of the motor, the dynamo speed drops too low to generate the required voltage for charging. The most suitable dynamo speed will then be such as to give a voltage on open circuit of 7 or 8 volts for charging a two-cell battery, and 9 to 10 volts for a three-cell battery.

59. All ignition dynamos have self-exciting field magnets, and from this fact they have a tendency to oversensi-

tiveness, by which is meant that the current they give is more dependent than it should be on the speed of the machine. The reason for this is clear when it is remembered that an increase in speed of the armature not only increases the voltage of the armature current, but, as part of this current is used to excite the field magnets, intensifies the magnetic field also, producing a still further increase in the intensity of the induced current in the armature. This is one of the principal reasons for employing a centrifugal governor, by which the speed of the dynamo is prevented from becoming excessive. Of course, another reason for the use of a governor is to avoid unnecessary mechanical wear and tear, which would be considerable with working speeds in excess of from 1,200 to 1,500 revolutions per minute. Another device that partly remedies the oversensitiveness just mentioned is to oversaturate the field coils; or, in other words, to wind them so that the soft-iron core will be fully magnetized at a comparatively low armature speed. From that point, as the armature speed increases, the increase in intensity of the fields is comparatively small, but of course the armature voltage is still free to increase in proportion to the armature speed.

60. An objection to the direct use of the dynamo as a source of ignition current is that it is liable to give an excessively hot spark that quite rapidly burns away the contact points of the tremblers on the coil, and may even endanger the insulation of the coils themselves. Moreover, the considerable number of coils of fine wire on the armature necessarily involves greater danger of an electrical breakdown than a smaller number of coils of coarse wire would.

MAGNETOS

61. For the foregoing and other reasons, preference is frequently given to certain forms of magneto-generators having permanent field magnets whose intensity is unaffected by the speed of the machine, and which have armatures

of the simple **H** type with but a single coil of comparatively coarse wire. These magnetos can be made very light, and the fact that the current induced in the armature fluctuates from zero to a maximum twice in each revolution is not a disadvantage, because the armature is always run in step, or synchronism, with the engine, and the circuit is broken for the spark when the armature current has its maximum value. *Running in step*, or *synchronism*, means that the rotations of the armature shaft and of the engine shaft are so timed that the maximum voltage of the current occurs at the point of the rotation of the engine shaft where the explosion should occur. By reason of the fact that the field magnetism is definitely limited and the armature can turn no faster than the engine, a magneto may be directly short-circuited on itself without injury, and this fact alone is of great value in protecting these machines from accidental electrical injury. Magnetos, like dynamos, are used for both primary and secondary-current ignition.

62. In all continuous-current machines, the current, as it comes from the armature coils, is commutated at the brushes so that a direct current is delivered to the circuit. In an ignition magneto, however, the direction of the current is of no consequence, and of the two terminals of the coil one is simply grounded on the armature core, while the other is led to an insulated collector ring on the shaft, from which it is taken off by a single brush. This results, on each alternate reversal of the current, in the grounded terminal being positive, instead of negative as conventional practice requires, and to guard against short circuits very careful insulation is required.

63. When an **H** armature is run in step, or synchronism, with the crank-shaft of a four-cylinder engine, it is only necessary to interrupt the armature circuit twice in each revolution at or near the points in the revolution where the current is the greatest. To insure the current being a maximum at the moment of ignition, the armature shaft may be

rotated with reference to the engine shaft when the ignition time is changed, this being done by the use of a sleeve with an external spiral groove and an internal straight feather, which is interposed between the armature shaft and its pinion. By shifting this sleeve lengthwise, the armature is rotated through a limited angle in relation to the engine shaft.

64. If the induced current is sufficient, it may be unnecessary to break the circuit exactly at the point where the current is greatest, and the sliding sleeve may be dispensed with. In this case, it is customary to break the circuit with the current near its maximum when the engine is running at its highest speed, in order to give the most rapid inflammation when it is most needed, and to permit the break to take place with a lower current when the speed is not so high. Owing to the intensity of the magneto-current, it is found that very little advance is required, compared with what is necessary with a battery current.

65. Low-Tension Magnetos.—So far, the description of the magneto applies to both the low and the high-tension types. The low-tension magneto is operated in connection with a make-and-break primary spark device. When used on automobiles, it is somewhat lighter in construction than on stationary engines, owing to the higher speed at which automobile engines run.

66. A diagrammatic illustration of the armature core and pole pieces of a special type of low-tension magneto employed in connection with make-and-break devices is shown in Fig. 26. In this magneto, the armature *a* is stationary in the position shown, and it is enough smaller than the pole pieces *b*, *b* to permit a soft-iron screen *c* to pass between them. The effect of this screen is to divert the lines of force at each eighth of a revolution, sending them alternately through the body of the armature core and through the ends, as shown by the dotted arrows. Since this reverses the current four times in each revolution,

instead of twice, as is the case with the ordinary rotating armature, it will be evident that the induced voltage is much higher, making it possible to build this magneto so as to be very light in proportion to its output.

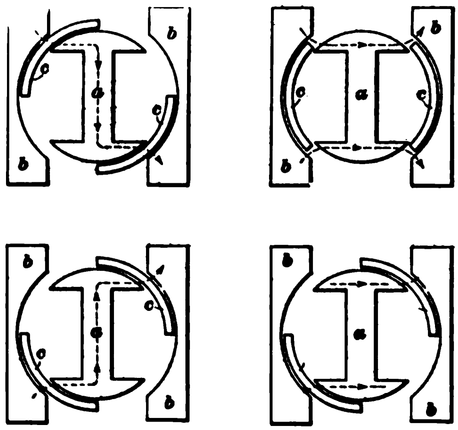


FIG. 26

67. Another low-tension magneto is shown in cross-section and longitudinal section in Fig. 27. It is driven by gearing at the speed of the engine, the gears being set so that the range of the spark timer coincides with the effective range of the magneto-current. The armature positions determining the latter are marked on the magneto, and it is unnecessary to change the angular relation of the

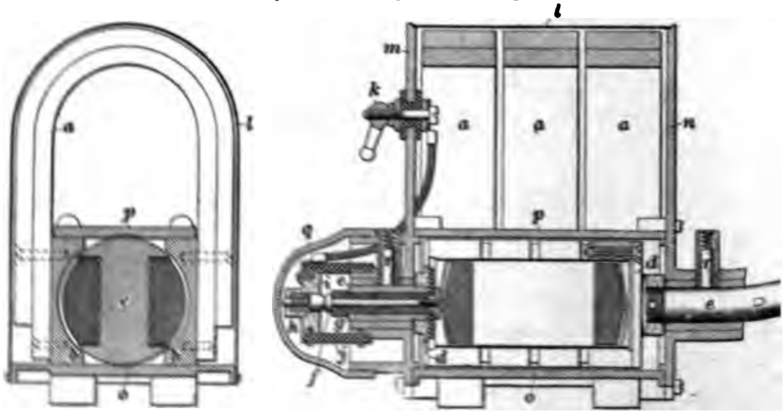


FIG. 27

armature to the engine crank-shaft when the spark is advanced or retarded. The principal features of construction are as follows:

The permanent magnets *a* have cast-iron pole pieces *b* fastened to them by screws. The cast-iron armature core *c* is wound with double silk-covered magneto-wire, and the ends of the core are screwed to hard brass disks *d*, into which the two shaft sections *e*, *e* are screwed and riveted. The object of this construction is to make a neater and more compact winding of the armature than would be possible if the shaft passed right through the core. One of the terminals is insulated, while the other is grounded on the frame of the generator. The insulated terminal of the coil is connected to a hardened-steel bolt *f*, insulated by a mica bushing *g* through the armature shaft, and the current is taken off by a hardened-steel contact pin *h* in the brass mounting *i*, carried by the hard-rubber tube *j* screwed over the end of the bearing. From *i*, a flexible connector leads to the binding post *k*. The entire magneto is provided with an aluminum housing comprising a sheet cover *l*, and cast end plates *m* and *n*, together with top and bottom yokes *o* and *p*, and a cap *q* to exclude dust. The shaft is oiled by oilers *r*, *r*. The magneto is used without a spark coil, the binding post *k* being connected to the insulated electrode of a make-and-break igniter. The extra current required to give a large spark is supplied by the self-induction of the armature.

68. High-Tension Magnetos.—High-tension magnetos may be divided into two general classes: those that simply take the place of the battery and timer and deliver current to an induction coil of the ordinary construction, in which the secondary current is induced; and those that comprise in their construction all the elements of generator, timer, and induction coil. One of the former type is shown in different views in Figs. 28 and 29. The generator portion of this magneto is substantially the same as that of the low-tension magneto shown in Fig. 27. The current is collected from the insulated bolt *a* in the armature shaft by means of a small bronze bearing *b*, provided with an oiler, and bearing against a stationary pin to prevent it from rotating. The other end of the armature shaft carries the timer or

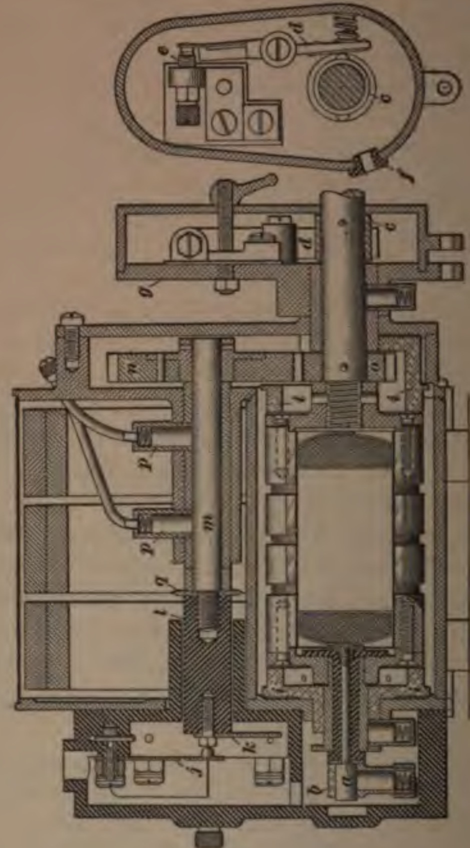


FIG. 29

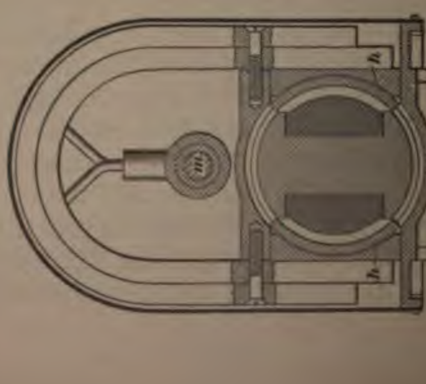


FIG. 28

interrupter, which has a two-lobed steel cam *c* that works against a rocking arm *d* pivoted at its center. Contact is made between the screw *e* and a spring carried by the rocking arm *d*, and when the latter is tripped by the cam the upper end of the arm strikes the spring a blow that effects a quick separation of the contact points. The current is taken from the collector *b* to the spark coil and from the spark coil it passes through the rubber bushing *f* to the insulated contact screw *e*, and then through the frame of the magneto to the grounded terminal of the armature winding. The spark time is changed by rocking the housing *g* of the timer on its axis. This at the same time changes the point of maximum current in the armature winding in the following manner:

The armature is surrounded by two soft-iron sectors *h*, *h*, Fig. 28, forming magnetic bridges somewhat similar to the screen of the magneto shown in Fig. 26. These are carried on brass end plates *i*, *i*, Fig. 29, secured to hubs that furnish bearings for the armature shafts. These hubs are supported in the end plates of the aluminum housing, and one of them has the timer housing fastened to it at its outer end. Consequently, the sectors *h*, *h* are rocked with the timer, and in this manner the direction of the magnetic lines through the armature is changed. The effect is the same as if the pole pieces themselves were rocked to change the point of maximum induction.

69. The armature runs at the same speed as the engine, and delivers two sparks per revolution, one for each cylinder in turn. The spark coil is not provided with a trembler, only a single spark being produced at each rupture of the circuit by the timer. The positive terminal of the secondary winding of the coil is carried by an insulated cable, through the top of the hard-rubber housing at the left end of the magneto, to a binding post connected to the flat spring *j*. From this spring the current goes to the revolving distributor arm *k*, and is taken off by four insulated contact pins connected to the several spark plugs. The

hard-rubber rod *l* carrying *k* is supported and rotated by the shaft *m*, which is driven by the gear *n* and pinion *o* at one-half the speed of the armature shaft. The oilers *p* keep the shaft lubricated, and the centrifugal oil flange *q* prevents any surplus oil from reaching the hard rubber.

70. The high-tension magneto just described, although very simple, does not attain the highest efficiency possible in apparatus of this type. It is apparent that in this class of magneto the extra current self-induced in the armature winding or the primary coil, which is utilized to give the spark in the primary ignition system, is objectionable because it prevents the instantaneous cessation of magnetism essential to the inducing of an energetic current in the secondary winding, exactly as when a battery is employed with a jump-spark coil. This momentary extra current is therefore absorbed by a condenser, and got rid of as far as possible. So far as it cannot be got rid of, it manifests itself by burning the contact points of the trembler and the timer, necessitating occasional cleaning or renewal.

71. In Fig. 30, suppose that *a* is the armature winding; *b*, the timing cam (arranged in this case for a single-cylinder

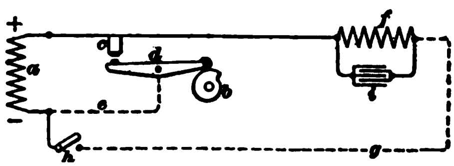


FIG. 30

engine); and *c*, the contact maker, the lever *d* being supposed to be pivoted at its center, as in the timer shown in Fig. 29. The circuit is completed from the timer to the negative terminal of the armature coil through the engine frame, represented by the dotted line *e*. Suppose an induction coil of the familiar sort to have a primary winding *f*, and grounded return connection *g*, whose switch *h* is normally closed. The secondary circuit is not shown. Furthermore, suppose that the primary winding is of moderately

high resistance, and that the contacts of the timer are normally closed, thus short-circuiting the armature on itself except at the moment of rupture, when it is desired to produce a spark. As was just explained, a magneto can be short-circuited without injury; but the current in the armature and coil will be high. If, now, the contact at *c* is broken when the current is at its maximum intensity, the result is not a complete breaking of the return path for the current, since the path through *f–g–h* is still open. Nevertheless, the resistance of this path is considerably greater than the direct path through *c–d–e*. Considerable extra current will be induced and will necessarily travel through *f*. By this arrangement, it is seen that the momentary extra current, which is much more energetic than the regular current generated by *a*, even when the latter is short-circuited, owing to the large current generated by the magneto on short circuit, is usefully applied to induce the secondary current in the spark coil.

72. The location of the switch *h* shown in Fig. 30, although somewhat common, is incorrect, since if it is left open it entirely deprives the armature of a path for the extra current, and produces excessive sparking at the contact points *c*, where there ought to be no sparking at all. This is corrected by arranging the circuit as shown in Fig. 31, in which the switch is so located as to short-circuit

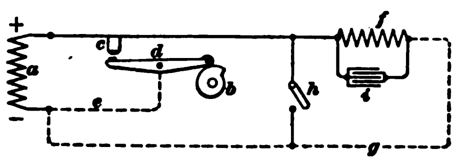


FIG. 31

the coil *f* when closed. With this arrangement, the switch is opened when it is desired to use the coil, and is closed to stop the current, which is the reverse of the usual arrangement. Its effect is simply to let *a* run short-circuited as long as the switch is closed.

73. Another magneto, the arrangement of which is shown in diagrammatic form in Fig. 32, does not depend on the momentary extra current, and differs from others in that no induction coil is used, the armature core itself serving the

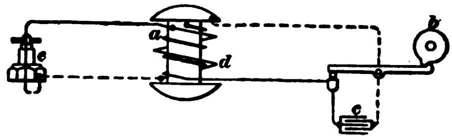


FIG. 32

purpose of a coil. The heavy line *a* indicates the primary winding on the armature core. Rupture is produced by a timing cam *b*, while a condenser *c* absorbs the extra current on rupture. The armature, however, is provided with a secondary winding *d*, in which the current for the spark plug *e* is induced. This system has the advantage of simplicity.

74. A very ingenious high-tension magneto, sectional and end views of which are shown in Fig. 33, depends

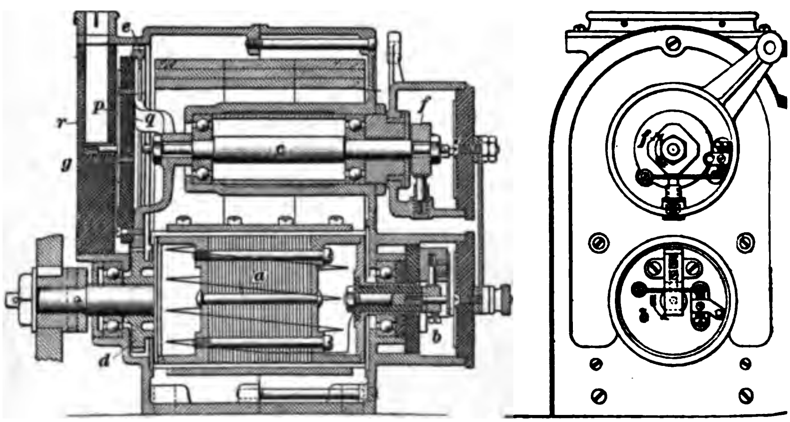


FIG. 33

neither on simple rupture of the primary nor on directly utilizing the momentary extra current. Instead, the primary current is used simply to charge a condenser, and the spark is induced in the secondary winding by the discharge

of this condenser through the primary winding of an induction coil. Thus, the contact make-and-break by which the condenser is charged does not need to have its timing changed, the only change in time being that connected with the condenser discharge. The coil is equipped with a vibrator, but the vibrator itself is employed only in starting, for which a battery is used, and is inoperative when the current is supplied by the magneto.

75. The armature is of the **H** type with laminated core *a*, and runs in ball bearings. On the armature shaft is mounted the regular primary interrupter *b*, having a circular cam with two lobes, thus making and breaking the circuit once for each stroke of the engine, which is here supposed to have four cylinders. A second shaft *c* is run by the pinion and gear *d* and *e* at one-half the speed of the armature, and carries a four-lobed primary contact maker *f* and also the secondary current distributor *g*. Fig. 34 shows the wiring connections. One end of the armature winding is grounded on the core, as usual, and the other is connected to the interrupter *b*, and

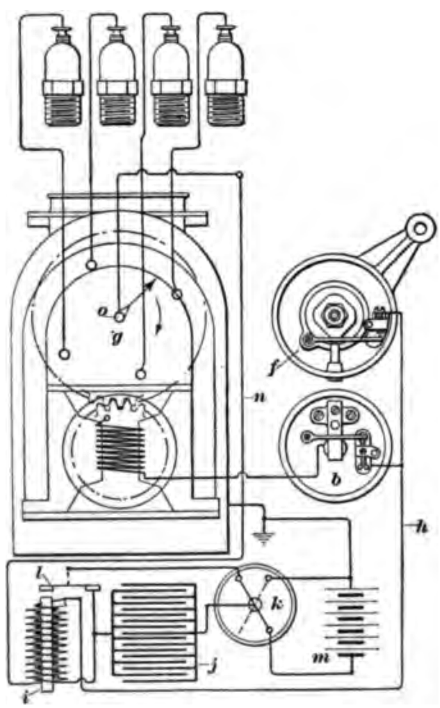


FIG. 34

through the wire *h* to the primary of the induction coil *i*. The other terminal of the primary is connected to the coil vibrator and also to the condenser *j*. A switch *k* has its

blade connected with the other condenser terminal, and has the three contacts connected, respectively, to the vibrator *l* and the positive and negative terminals of the battery *m*, as shown. The positive terminal of the battery is grounded.

76. When the switch is in the position shown by the dotted lines, and the circuit is closed by the primary interrupter *b*, a charge of electricity passes through the wire *h* and primary winding of the coil *i* into the condenser *j*. As soon as the condenser is charged, which takes but an instant, no further current can flow, as there is no return to the grounded terminal of the armature. The circuit is then broken, leaving the condenser charged, and at the proper moment for the spark a contact is made by the timer *f*, thus grounding the wire *h* and permitting the condenser to discharge itself through the primary winding of the coil *i*, the flow being now in the opposite direction to that of the momentary charging current. The discharge of the condenser is so sudden as to induce a very high momentary voltage in the secondary winding of the coil.

77. As one end of the secondary winding is connected to the primary winding, the secondary winding is grounded while the timer *f* is making contact. The other end of the secondary winding is connected by the cable *n* to the central terminal *o* of the high-tension distributor *g*, whose arm *p*, Fig. 33, is secured to the rotating hard-rubber disk *q* attached to the shaft *c*. Four fixed terminals, mounted in the same hard-rubber piece *r* that holds the central terminal, distribute the current to the spark plugs. As the end of the arm *p* is widened, no advance is required in the distributor, and hence the timer *f*, Fig. 34, is the only member moved to change the spark time, the condenser simply remaining charged, between the moments of contact, by *b* and *f*, respectively.

As already stated, the battery furnishes current for starting, the switch *k* then being turned to the position shown in full lines in the diagram. The magneto is thereby disconnected, and the battery current goes through the engine

frame, contact maker *f*, wire *k*, primary winding of the coil, vibrator *l*, and the switch. The current can also go by way of the armature winding and interrupter *b*; but, if the vibrator is adjusted for the current reaching the coil by the more direct route, it will not respond to the weaker current. When the engine reaches normal speed, the switch is thrown over by the operator. The switch is of special design, and is very highly insulated to protect the operator from shocks. It is claimed that this magneto will produce a 3-inch spark in the open air at 600 revolutions per minute, and a ⅜-inch spark at 50 revolutions per minute. As but a single spark is produced, it can be timed with perfect accuracy.

CARE OF DYNAMOS AND MAGNETOS

78. A magneto or dynamo requires little care except to see that it is mechanically in good order. The bearings should be oiled at proper intervals, and the commutator touched now and then with an oily rag. The brushes should be watched to see that they bear evenly and with sufficient pressure to prevent sparking. Copper or carbon dust from the commutator will gradually collect on the wires leading to the commutator, if these are exposed. So long as it does not short-circuit the wires it does no harm, but it should be brushed off now and then.

The distributor of a high-tension magneto is likely to produce metal dust from the rubbing of the contact points, and when this lodges on the hard-rubber mounting it will in time lead to a short circuit from one high-tension terminal to the next. It should be wiped off frequently with a slightly oily rag, and the film of oil left will serve the further purpose of preventing moisture from forming on the hard rubber, which would be as bad as the dust. On account of the high secondary tension, great care is necessary to maintain perfect insulation.

79. All switches of magnetos should be heavily insulated. If necessary, a rubber tube may be slipped over the

switch handle. As the current is very strong, the shocks that might be received by careless handling would be most violent. With magnetos of the type shown in Fig. 26, a secondary wire should not be disconnected and left where no spark can jump when the engine is running. This would put a severe stress on the insulation, which might ultimately break down. This is a good rule to follow with all jump-spark systems, both magneto and battery.

Some high-tension magnetos work best with a smaller spark gap than is used with primary battery ignition, it being about one-half the length used with a primary battery. In the absence of instructions from the maker, the length of spark is best determined by trial.

SWITCHES

80. Knife switches such as are shown in Fig. 35 (*a*), (*b*), and (*c*), are commonly used in marine and stationary practice. While the copper or brass used in them is liable to oxidation, they give the best service on motor boats because the action of opening and closing them tends to keep the contacts bright. The single-pole knife switch, Fig. 35 (*a*), has a detachable knife lever *a* that may be carried in one's pocket to prevent unauthorized use of the boat or automobile. There are three contact points *b*, *c*, and *d*. When the knife *a* is thrown in at *b*, connection is made with one set of batteries, and with another set when thrown in at *d*. When both batteries have been weakened through use, the blade may be thrown in at *c*, connecting the batteries in parallel series and thus increasing the strength of the current delivered. What is known as a *double-pole single-throw knife switch* is shown in Fig. 35 (*b*); while a switch of the same type but having a double throw is illustrated in Fig. 35 (*c*). Wires from two sets of cells or other sources of electric current are connected to the poles of the switch beneath the base plate, one set of wires leading to the poles *a* and *b*, the other set leading to the poles *c* and *d*, connection with the

external circuit being made through the posts *e* and *f*, in which the knife blades are pivoted.

(a)

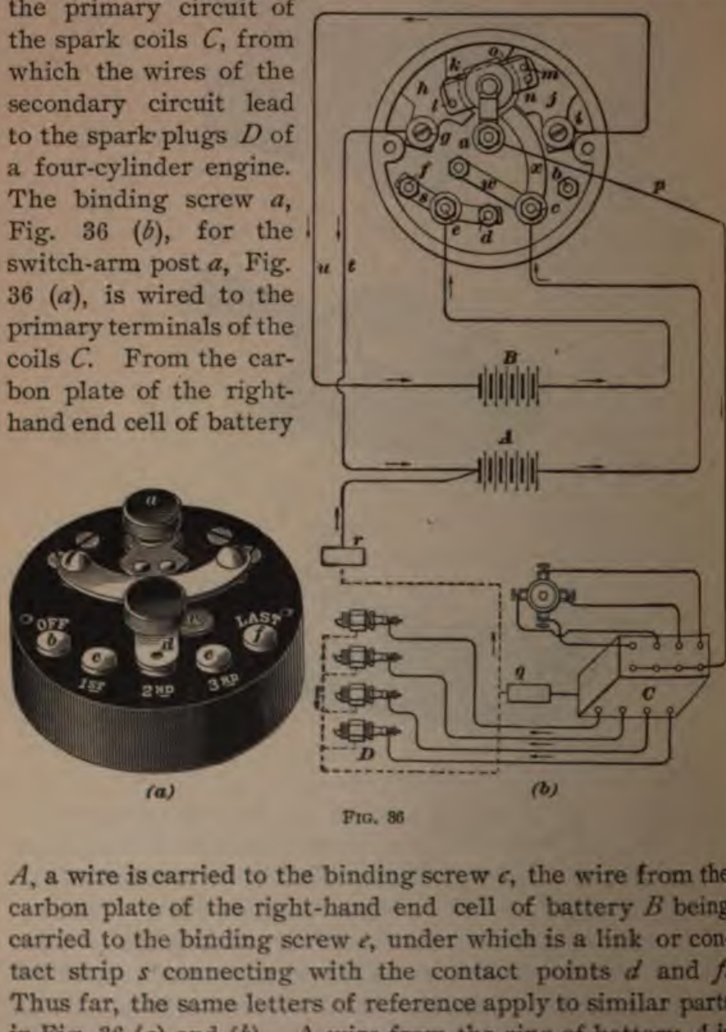
(b)

(c)

FIG. 35

81. Fig. 36 (*a*) and (*b*) shows the external appearance and system of wiring of a switch for use on automobiles or motor boats having single-cylinder or multi-cylinder engines, and with one or more sources of current. The contact points of the switch, as shown in Fig. 36 (*a*), are arranged so that, when the switch arm, or lever, attached to the post *a* rests on the button *b*, no current flows. When on *c*, one set of batteries is in use; when on *d*, the second set is in use; when on *e*, the batteries are connected up in

multiple series, increasing their ampere capacity; and when on *f*, the batteries are connected up in series, increasing the voltage. Fig. 36 (*b*) shows the switch wired for use with two sets of dry-cell batteries *A* and *B* supplying current for the primary circuit of the spark coils *C*, from which the wires of the secondary circuit lead to the spark plugs *D* of a four-cylinder engine. The binding screw *a*, Fig. 36 (*b*), for the switch-arm post *a*, Fig. 36 (*a*), is wired to the primary terminals of the coils *C*. From the carbon plate of the right-hand end cell of battery



(a) (b)

FIG. 36

A, a wire is carried to the binding screw *c*, the wire from the carbon plate of the right-hand end cell of battery *B* being carried to the binding screw *e*, under which is a link or contact strip *s* connecting with the contact points *d* and *f*. Thus far, the same letters of reference apply to similar parts in Fig. 36 (*a*) and (*b*). A wire from the zinc of battery *A* is connected to the binding screw *g* attached to the metal plate *k*.

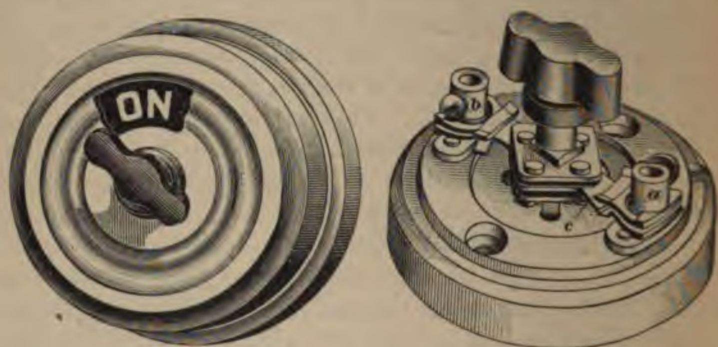
A wire from the zinc of battery *B* is connected to the binding screw *i* attached to the metal plate *j*. In a fiber plate *k* fixed on the post *a*, Fig. 36 (*a*), so as to turn with it when the switch arm is shifted, are mounted three contact pins *l*, *m*, and *n* that slide on the metal plates *h* and *j*. These pins are electrically connected by means of a wire *o* laid in a slot in the fiber plate *k* and soldered to the pins.

When the end of the switch arm rests on the contact point *c*, current flows from battery *A* to *c*, thence through the switch arm to *a*, thence by wire *p* to coils *C*, and by grounded connections *q* and *r* back to battery *A*. When the switch arm is on *d*, current flows from battery *B* to *e*, thence through the metal plate *s* to *d*, through switch arm to *a*, to coils *C*, to grounds *q* and *r*, wire *t* to binding screw *g* and plate *h*, pin *l*, wire *o*, pins *m* and *n*, plate *j*, screw *i*, and wire *u*, back to battery *B*. When the switch arm rests on *e*, it also makes contact with the auxiliary contact point *v*, Fig. 36 (*a*), which is connected to *c*, Fig. 36 (*b*), by means of the metal plate *w*. The two wires from the carbon plates of the right-hand end cells of the two batteries are thus connected together, the two wires from the zincs of the left-hand end cells of the two batteries being connected by means of the contact pins *l*, *m*, and *n*, wire *o*, and plates *h* and *j*. The batteries being thus connected up in multiple series, current flows through binding screw *e* and switch arm to *a*, then to coils *C*, grounds *q* and *r* to battery *A*, and to battery *B*, by way of wire *t*, binding screw *g*, plate *h*, pins *l*, *m*, and *n*, and wire *o*, plate *j*, screw *i*, and wire *u*. When the end of the switch arm is shifted into contact with *f*, the pin *l* is moved out of contact with the plate *h*, while the pin *n* makes contact with the metal plate *x*, thus connecting the carbon of battery *A* to the zinc of battery *B*, and thereby placing the batteries in series. Current then flows through the wire from the carbon plate of the right-hand end cell of battery *B* to *e*, then through plate *s* to *f*, through switch arm to *a*, to coils *C*, to grounds *q* and *r*, back to the left-hand end cell of battery *A*, thus completing the circuit.

To prevent unauthorized use of the automobile or motor

boat on which the switch is used, the contact post *a* is made removable.

82. Snap switches, the operative principle of which is illustrated in Fig. 37, are commonly used for opening and closing the primary ignition circuit in stationary and marine gas-engine practice. Fig. 37 shows a typical single-pole snap switch; the same type of switch is made double-pole—also, three-point and four-point. The wires from the battery or other source of primary current come through the porcelain base of the switch, and are held in posts *a*, *b*, which



(*a*) (*b*)

FIG. 37

also carry the switch contacts. When the switch is closed, the rotary cross-piece *c* makes connection between posts *a* and *b*, thus closing the circuit. A double-pole switch has two pieces *c* and four contact posts. It is desirable to have snap switches provided with an indicating dial, as shown in Fig. 37 (*a*), unless the position of the switch handle shows clearly whether the switch is "on" or "off."

83. A switch for use with high-tension currents where two sources of current are available, as where storage batteries and coils are installed together with a magneto, is shown in section in Fig. 38. By throwing the switch handle *a* to one side, the magneto-circuit is closed and the magneto

is in operation; throwing the switch handle to the other side cuts out the magneto, closes the battery-and-coil circuit, and places the batteries and coils in operation. The ball contacts *b* are held against the contacts *c* by the springs *d*, and are in electrical connection through the strip *e*. Wires from the two sources of current are led to the binding screws *f* and *g*, the common circuit-completing wire being attached at *h*.

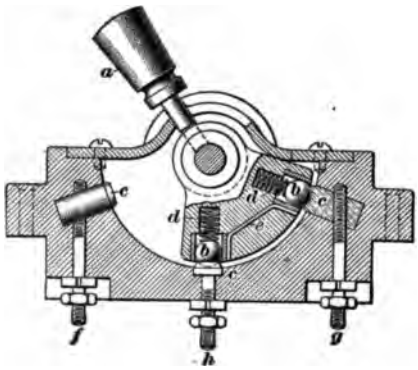


FIG. 38

WIRING

MAKE-AND-BREAK WIRING

84. The wiring diagram shown in Fig. 39 illustrates the usual method of wiring for a two-cylinder engine, the same scheme being equally applicable in making connections to multi-cylinder engines. When contact between the insulated and uninsulated electrodes of the igniter is made, current passes from the battery *a* through one blade of the switch *b* to the insulated electrode of the igniter *d*, then through the uninsulated electrode of the igniter to the grounded connection *e*, to the coil *c*, and back to the battery through the other blade of the switch *b*.

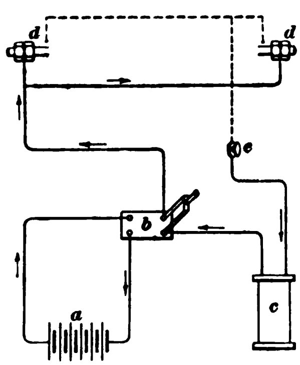


FIG. 39

85. Fig. 40 shows the wiring for a generator, or dynamo *f*, and one set of batteries. The spark coil *c*, Figs. 39 and 40,

is located between the ground on the engine and the switch. The object of this is to provide means for connecting

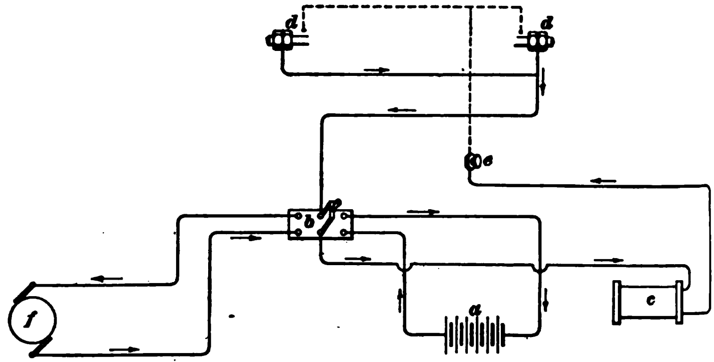


FIG. 40

another set of batteries, using the same terminals as are used for the generator *f*.

86. Fig. 41 shows two of the cylinders of a four-cylinder engine connected to one set of batteries, and the other two

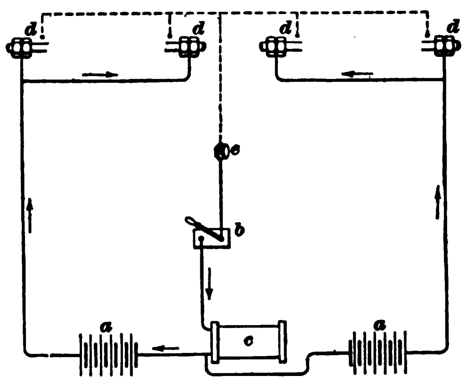


FIG. 41

connected to a separate set. It should be noted that the batteries are so located as to make it easy to connect the cells so as to double the amperage when the batteries become nearly exhausted.

87. Fig. 42 shows a double system of wiring for a four-cylinder engine with two coils and two sets of batteries. One coil could be removed by connecting the two points of the switches that are wired to the coils and placing one wire of a single coil in connection with the engine

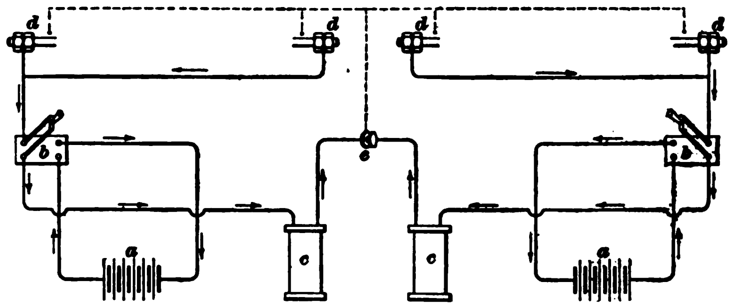


FIG. 42

ground while the other is connected to the wire joining the two switch points. If both switches should happen to be closed at the same time, the current from both batteries would pass through the coil, and the amperage would be doubled but the voltage would not be increased.

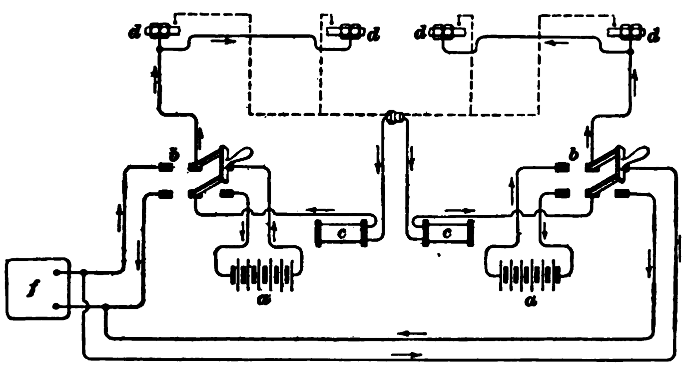


FIG. 43

88. Fig. 43 shows double wiring throughout, for a four-cylinder engine, with a generator so connected up that either pair of cylinders may be operated by either of two sets of

batteries *a*, *a*, or by a generator *f*, or all may be operated by both sets of batteries together, in case they may have become weak.

In connecting and setting up batteries successfully, it is only necessary to use a little thought, to reason out the complete circuit, which includes the engine ground, spark coil, batteries (or generator instead of batteries), switch, and insulated electrode.

JUMP-SPARK WIRING

89. In wiring an engine for jump-spark or high-tension ignition, there are two general systems: In one system, the primary, or low-tension, current is commutated or alternately closed and opened, and in the other a so-called distributor is employed to close and open the induced, or high-tension, circuit for each of the cylinders. The object of this second system is to obviate the use of a separate spark coil for each cylinder.

The first is the system most in use. The positive or the negative poles of the coils should be connected together and wired through the switch, battery, and generator or direct-current magneto to a ground on the engine. If the positive poles are connected, each positive pole of the secondary wiring should also be included in this connection, unless there is a connection in the coil itself. Wires should be run from each binding post on the commutator to its coil. The wire should be well insulated, and of the same size and quality as used in make-and-break ignition. All joints should be made carefully, to be sure of good contact. The secondary wiring, which carries a current often as high as 30,000 to 40,000 volts, should be specially made for the purpose, to avoid dangerous and faulty leaks of current. It should be as short as convenient, should be kept away from metal work of all kinds as much as possible, including parts of the engine, and should connect the spark plugs with their respective coils. There is so much more dampness (particularly around salt water) in boats than in automobiles that

electrical losses due to leakage are more frequent in marine practice and have to be guarded against constantly.

90. In wiring for high-tension distribution, the primary circuit is completed from a ground on the engine or uninsulated part of the distributor through the coil and battery, generator, or direct-current magneto, and to the single insulated binding post on the distributor. The secondary binding post of the coil is connected to the primary, both being positive or negative; and, by means of heavy special secondary wire, the other secondary pole is connected to the single secondary binding post on the distributor, while secondary wiring connects each plug with its proper terminal on the distributor. In connecting the secondary binding post on the coil, it is necessary to be sure that it is on the side leading to the engine ground rather than to the insulated electrode on the distributor.

The wiring of a marine gas engine should be very carefully done, particularly if the current is of high tension; for, unless the very best material is used, and the work is done properly, there will be positive danger from explosion or fire. For this reason, manufacturers generally recommend make-and-break ignition when the engine is installed in a cabin or other enclosed space. Fire-insurance rates on such craft are high, and risks are hard to place.

IGNITION WIRE CABLE

91. High and low-tension wire cable, such as is commonly used on automobiles and motor boats, is shown in Fig. 44 (*a*) and (*b*). The primary, or low-tension, cable is shown at (*a*). The wire core of the cable consists of forty strands of No. 30 tinned copper wire. The insulation consists of one layer of high-grade vulcanized rubber *a*, while the protective covering consists of two braids *c* and *d* covered with two layers of enameled coating baked on. It would take about 12,000 volts to puncture this insulation. The core of the high-tension cable (*b*) is the same as that of the

low-tension cable. The insulation consists of three layers of rubber *a*, *b*, *c*, vulcanized together. The rubber is protected by two braids *e* and *f*, covered with four coats of enamel

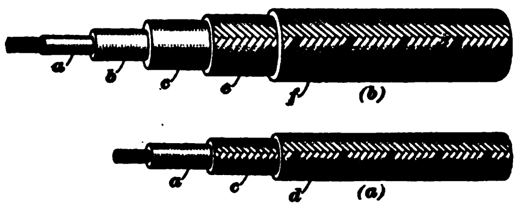


FIG. 44

baked on in steam-heated ovens. The enamel forms a flexible, insoluble film that protects the rubber from heat, oil, and water, the braid protecting the cable against mechanical injury. More than 40,000 volts is necessary to puncture this cable.

AUTOMOBILE AND MARINE ENGINE AUXILIARIES

TRANSMISSION MECHANISM

SPEED-CHANGING SYSTEMS

1. Every automobile driven by an internal-combustion engine is provided with means for changing the ratio of gearing, and for reversing, between the engine and the point where the power is used. The power is utilized at the rear axle, the rear wheels being the driving wheels. The engine, or driving, shaft and the driven, or propeller, shaft are separate, and provision is made between them for changing the speed and reversing by means of gears called *speed-change gears*. The reason for providing such speed-change gears is that the internal-combustion engine gives its highest efficiency when working with full charges. Consequently, it is desirable to operate the engine under those conditions as much of the time as possible, modifying the speed of the automobile by changing the gear ratio to suit the power actually developed.

Motor boats are generally provided with a reversing mechanism, having only one forward and one reverse speed.

2. The automobile engine is proportioned and geared so as to drive the car at maximum speed on a smooth road when the throttle is fully open. If the road or grade

resistance increases, the car necessarily slows down to a point where the resulting reduction in the resistance of the air or wind offsets the increase in road or grade resistance, and if this speed of the car is insufficient for the engine to run properly the gear ratio must be increased to enable the engine to carry the load. This simply means that, while the engine speed is unchanged, the speed of the car is reduced by the change of gears. Every gasoline automobile has at least two choices of gear ratios for forward motion, in addition to a single slow-speed reverse-gear movement. In the higher-powered cars, three and often four gear changes are provided, by which means the engine may always be run at approximately the most advantageous speed to get the power it is capable of developing. These gear changes are convenient also when it is desired to run the car slowly, since even with the best carbureter and the best engine design, it is impossible to run a gasoline engine effectively below a certain speed, which is generally between 200 and 400 revolutions per minute. If a lower car speed is desired it is obtained by using one of the lower speed gears.

There are in common use three systems of speed-changing gears, commonly known as **transmission gears**; namely, the *sliding-gear system*, the *individual-clutch system*, and the *planetary system*.

SLIDING-GEAR TRANSMISSION SYSTEM

3. In Fig. 1 is shown a plan view, with body removed, of a small touring car equipped with a four-cylinder gasoline engine *a* and sliding-gear transmission *b*. From the speed-changing gears the power is transmitted through a jointed propeller shaft *c* and bevel pinion and gear, enclosed at *d*, to the rear axle *e*. Attached to the engine shaft is the flywheel *f* carrying a friction clutch, and just back of the clutch is a coupling *g* connecting the clutch with the speed-changing gears. At *h* is a brake; at *i* and *j* are universal joints, which will be described later; and at *k* and *l* are hub brakes. In this transmission system the drive is *direct*, as it

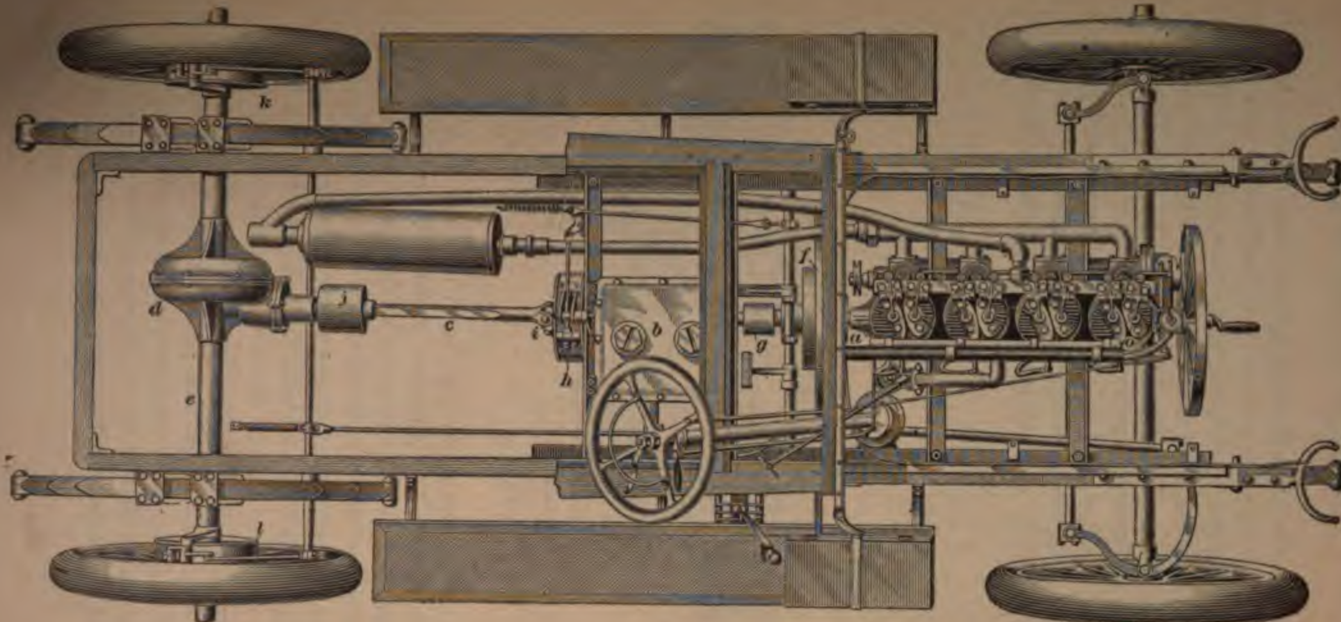


FIG. 1

is called, in the high-speed gear. In the slow and intermediate gear positions, generally called the *first* and *second gears*, the power is transmitted from a pinion on the engine shaft to a gear on a lay shaft, or jack-shaft, and from a pinion on the lay shaft back to a gear on the propeller shaft in line with the pinion first mentioned.

In Figs. 2, 3, 4, and 5 is shown a sliding-gear system with three forward speeds and one reverse speed. The coupling shown at *a*, Fig. 2, connects the short shaft *b* to the engine

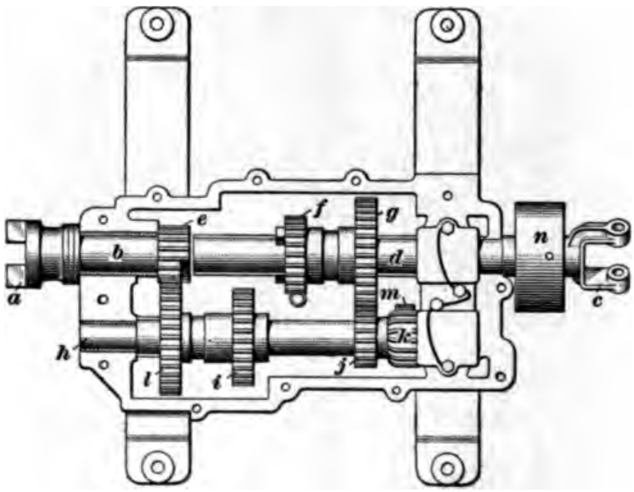


FIG. 2

shaft, while the coupling *c* at the other end connects the short shaft *d* to the propeller shaft. The shafts *b* and *d* are separated close to the gear *e*, which is keyed to the shaft *b* and has a portion of a coupling on the side toward the gear *f* to which is connected the other portion of the coupling. The gears *f* and *g* are fastened together by a sleeve that slides on a feather in the shaft *d*; it should be noticed that the gear *f* is smaller in diameter than the gear *g*. The lay shaft *h* carries the gears *i*, *j*, and *k* that are keyed to it and the gear *l* on a sleeve that slides on a feather. The gear *k* is slightly smaller than the gear *j*, so that, when the gear *g* is moved to the extreme right, it does not mesh with *k* but

with a small idle pinion *m* that is in mesh with *k*. A brake is shown at *n* on the shaft *d*.

4. In the position shown in Fig. 2, the transmission system is set for the slow forward speed of the car; the gear *l* is in mesh with the smaller gear *e*, reducing the speed of the shaft *h*, while the gear *j* meshes with the larger gear *g*, again reducing the speed so that the shaft *d* turns slower than *h* and much slower than the shaft *b*.

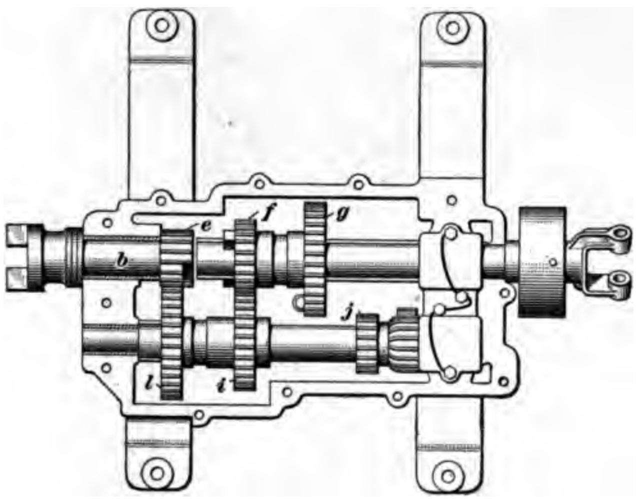


FIG. 3

In Fig. 3 the gears are shown set for the intermediate forward speed, with the gears *e* and *l* still in mesh; but the gear *i*, which is larger than the gear *j*, is in mesh with the gear *f*, which is smaller than the gear *g*. Consequently, the speed reduction from the shaft *b* to *d* is less than in the case shown in Fig. 2.

In Fig. 4 the gears are set for the high forward speed. The gear *l* has been moved out of mesh with the gear *e*, and the sleeve carrying *f* and *g* has been moved so that the clutch on *f* engages with that on gear *e* and the two shafts *b* and *d* are locked together and turn as one shaft, there being no gears

in mesh. The propeller therefore rotates at the same spe
as the engine shaft.

In Fig. 5 the gears are shown in position for the rever

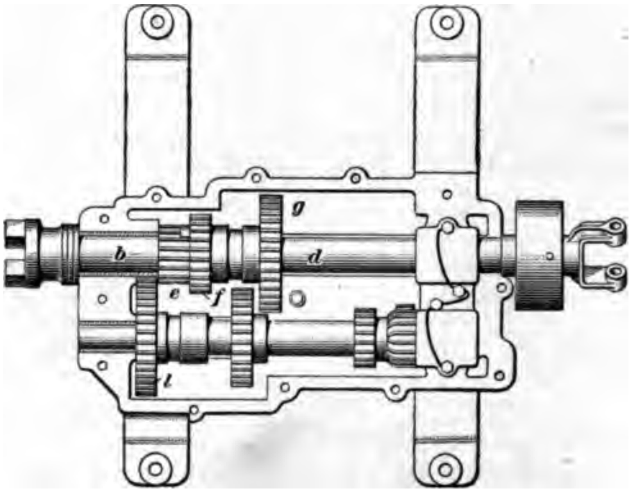


FIG. 4

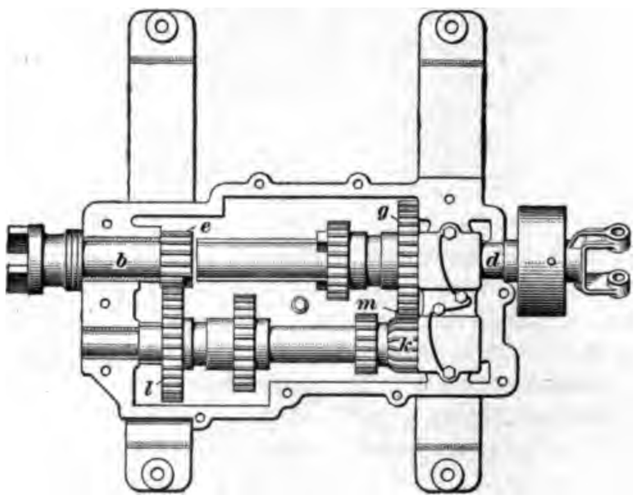


FIG. 5

motion. The gears *e* and *l* are again in mesh, but the gear *g* is in its farthest position to the right and in mesh with the

idler *m* that is behind and in mesh with the gear *k*. Consequently, the shafts *b* and *d* turn in opposite directions, and the propeller shaft runs at the reverse speed, giving a backward motion to the automobile.

To avoid shocks in changing gears, the coupling *a*, Fig. 2, is not connected directly to the motor shaft, but is connected to one member of a friction clutch partly enclosed in the flywheel, shown at *f*, Fig. 1, and this clutch is invariably released before changing gears. In this manner the shock involved in changing gears is confined to that necessary to alter the speed of the gears themselves and of the part of the clutch connected to *a*, Fig. 2. The gears are made of a special tough steel suitably treated to enable them to withstand this shock. As a single clutch is used for all speeds, it is made with a very large surface, so that the wear on it is almost negligible.

INDIVIDUAL-CLUTCH TRANSMISSION SYSTEM

5. In the individual-clutch system there is a separate friction clutch for each speed. In Fig. 6 is shown a system with two forward speeds and one reverse. The flywheel *a* is keyed to the engine shaft and is connected to the shaft *b* by the coupling *c*. From the shaft *b*, motion is transmitted to the propeller shaft *d* through the different clutches and gears. Keyed to the short shaft *b* are the gears *e* and *f* and the friction cones *g* and *h*. The gear *i* and the clutch disk *j* are parts of the same piece, which is provided with a bushing *k* that fits loosely on the shaft *b* and is free to rotate on the shaft. The collar *l* is loose on the shaft *b* and can be moved by the lever *m* so as to force the end of the dog *n* against the friction plate *o* and thus force the pin *p* against the cone *g*.

On the lay shaft *q* is keyed the gear *r*, but the gears *s* and *t*, which are provided with bushings, fit loosely on the shaft. The friction cones *u* and *v* are keyed to the shaft *q*, as are also the friction plates *w* and *x*. The collar *y* also fits loosely on the shaft *q* and operates on the

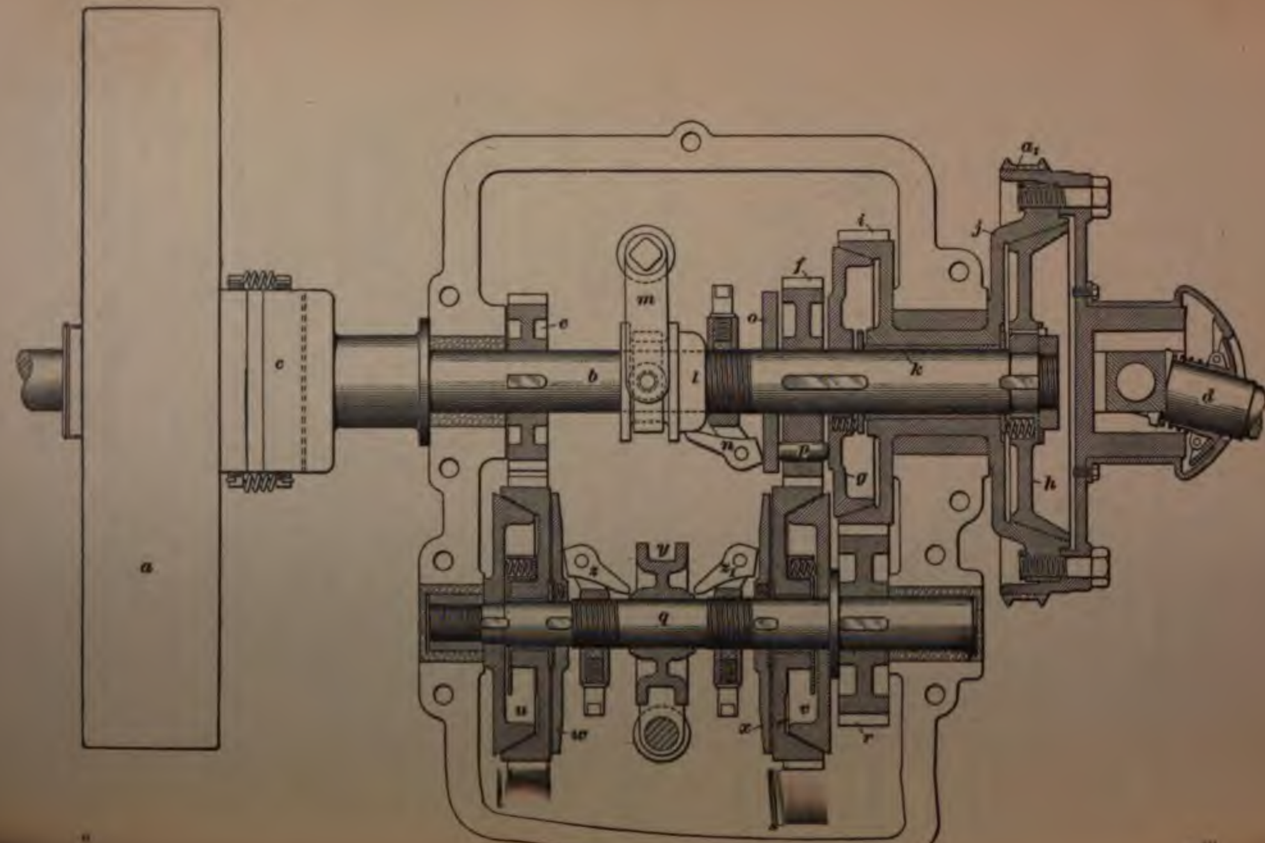


FIG. 6

dogs *z* and z_1, throwing one or the other of them against its friction plate and putting that gear into operation. There is a small idle gear that stands behind but meshes with the gears *t* and *e*. There is also a brake band at a_1, that may be used to prevent *i* and *j* from turning, or to bring the moving parts to rest.

6. In the position shown in Fig. 6, the collar *l* has pushed out the long end of the dog *n* and forced the friction plate *o* against the pin *p*, causing it to force the cone *g* into the gear *i* and the clutch disk *j* on the cone *h*, thus locking the shafts *b* and *d* together. Consequently, the propeller shaft turns with the same speed as the engine itself, which is the highest speed that is transmitted. When the collar *l* releases the dog *n*, the cones *g* and *h* are disengaged by the pressure of the small springs shown in the hubs of these cones.

When a slow forward speed is desired, the collar *y* is forced to the right, moving the long arm of the dog z_1 out, forcing the friction plate *x* against the gear *s*, and the gear on the cone *v*. Consequently, motion is transmitted from the shaft *b* to the shaft *q* by the gears *f* and *s* and the friction clutch *v*. From the shaft *q*, motion is transmitted by the gear *r* to the gear *i* and thence to the shaft *d*. It should be noted that, as the gear *f* is smaller than the gear *s*, the shaft *q* turns more slowly than the shaft *b*, and, as the gear *r* is smaller than the gear *i*, which is rigidly attached to the shaft *d*, the shaft *d* turns more slowly than the shaft *q* and therefore much more slowly than the engine shaft.

When the collar *y* is thrown to the left, the gear *t* is locked to the shaft, and, on account of the intermediate gear between *t* and *e*, the propeller shaft *d* turns in a direction opposite to that of the engine shaft—that is, the motion is reversed.

It should be noted that the gears *s* and *t* ordinarily run loose on the shaft *q* and turn the shaft only when held by the friction clutches. As these gears are constantly in mesh

with the gears *e* and *f* keyed to the shaft *b*, they produce unavoidable friction, as do also the friction clutches not engaged. On account of the unavoidable friction of the constantly meshing gears, and also the dragging of the disengaged clutches, this system is not very much used.

PLANETARY TRANSMISSION SYSTEM

7. Another speed-change system often used is known as the *planetary system*. It comprises a high-speed connection for the direct drive, and an arrangement of gears that reduces or reverses the motion when one or another drum

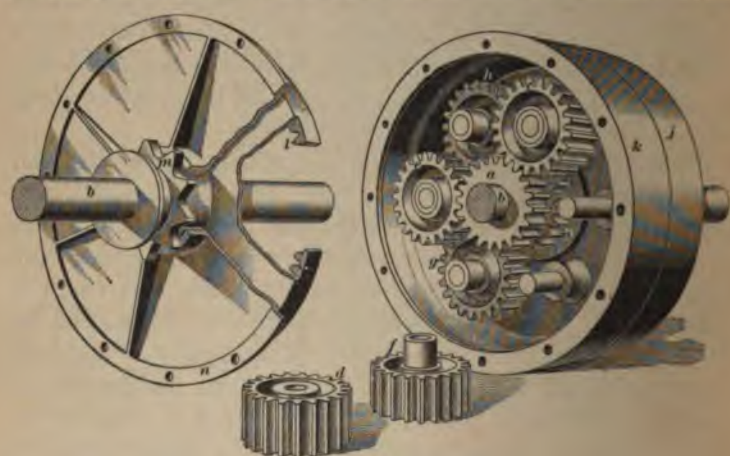


FIG. 7

on which these gears or pinions are mounted is held stationary. Most planetary systems give only two forward speeds and one reverse, but in some instances they are made to give three forward speeds. They are used chiefly on small automobiles, or runabouts; but when cheapness of construction is an object they are sometimes employed on touring cars.

In Fig. 7, is shown one form of planetary system. The gear *a* is the only one keyed to the engine shaft *b*. The gears *c*, *d*, and *e* all mesh with the gear *a*, and are made long enough to extend beyond *a* and mesh with the gears

f, *g*, and *h* in pairs. The last three gears in turn extend beyond the gears *c*, *d*, and *e* and mesh with the gear *i*, which is keyed to a sleeve connected to the drum *j*. The gears *c*, *d*, *e*, *f*, *g*, and *h* turn on pins fastened to the drum *k*, but only the gears *c*, *d*, and *e* mesh with *a*, and only *f*, *g*, and *h* mesh with the gear *i* which turns loosely on the shaft *b*. The internal gear *l* meshes only with the gears *c*, *d*, and *e*, and is rigidly connected to the sprocket *m* that drives the automobile. The cover *n* is attached to the face of the drum *k* by means of screws, thus forming an oil reservoir that keeps the gears well lubricated when the automobile is running. There are separate brake bands around the drums *j* and *k*, and a friction disk keyed to the shaft just outside of the drum *j*.

When the friction disk is pressed against the drum *j*, the gear *i* is held so that it must turn with the shaft; consequently, the entire mechanism is locked together and the sprocket *m* turns at its highest forward speed. If now the friction disk is released and the brake band around the drum *j* is applied so as to hold it from turning, then the gear *a* turns the gears *c*, *d*, and *e*, causing them to turn the gears *f*, *g*, and *h*; but, as the gear *i* is held stationary with the drum *j*, the gears *f*, *g*, and *h*, and also the drum *k*, to which they are attached, must revolve around the gear *i* in the same direction as the shaft turns, but more slowly. The gears *c*, *d*, and *e* turn on pins that are fastened to the drum *k*; consequently, they revolve with it as they turn on their axes and thus cause the internal gear *l* and the sprocket *m* to turn in the same direction as the shaft. This gives the slow forward speed.

When the drum *j* is released and the drum *k* is held by a brake band, the gears *c*, *d*, and *e* are caused to turn on their pins, and consequently drive the internal gear *l* in a direction opposite to that of the engine shaft, driving the automobile backwards. When the brake bands and friction disk are all free from the drums, the gears turn idly, and if the engine is running, no motion is transmitted to the sprocket and the automobile stands still.

REVERSING GEARS

8. In motor boats, it is often desirable to run the propeller backwards even when there is only one set of gears for forward speed and hence no speed-change device. In such cases, it is desirable to have a device by means of which the direction of motion of the propeller shaft may be reversed while the engine runs continually in the one direction. The reverse motion of the propeller is sometimes needed to check the forward speed of the boat, to bring it to rest, or to run it backwards. There are several forms of such reversing mechanisms, but they are all similar in principle so far as the motion of the engine and propeller shaft is concerned, differing only in the method of making the connections for the reversal of motion. In some cases, spur

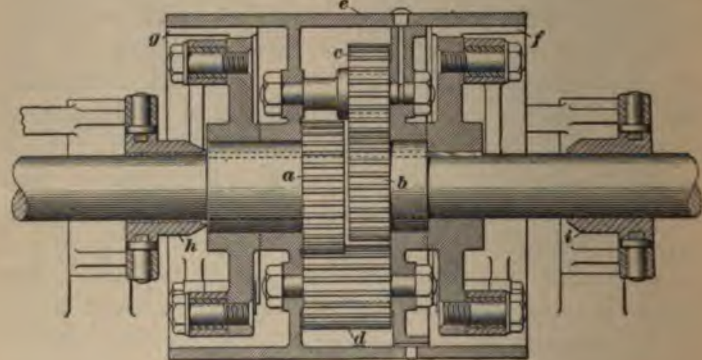


FIG. 8 (*a*)

gears and clutches are used; in others, spur gears and sliding feathers; and in still others, bevel gears.

In Fig 8 (*a*) is shown a reversing gear that depends on friction clutches for its operation. The propeller shaft is divided into two parts, the one connected to the propeller, carrying the gear *a*, and the other, connected to the engine, carrying the gear *b*. The gears *c* and *d* mesh with these gears, and it should be noted that the gear *b* is slightly smaller than the gear *a* and that *c* meshes with *b*, and *d*

with *a*. Another gear similar to *c*, but not shown, meshes with *d* and *b*, while one similar to *d* meshes with *a* and *c*. The gears *c* and *d* run on pins that are held in place in the web of the drum *e*.

There are two friction clutches *f* and *g*, the latter serving to hold the drum *e* stationary when the movement of the propeller shaft is to be reversed. To reverse the motion of the propeller shaft while the engine is running, the spreader *h* is thrown inwards by the reverse lever, so that the clutch *g*, which is stationary, grips the drum *e* and holds it. The pins on which the gears *c* and *d* revolve are thus also held stationary, and the relative motions of the gears are as shown diagrammatically in Fig. 8 (*b*). The crank-shaft transmits motion to the gear *b*, in the direction indicated by the arrow. The gear *c* in mesh with *b* turns in the opposite direction and transmits motion through a long gear *c'*, not shown in Fig. 8 (*a*), to the gear *a* on the propeller shaft, which is thus made to move in a direction opposite to that of the gear *b* on the end of the driving shaft. The gear *b* is also in mesh with the gear *d'*, which turns gear *d* in the same direction as that in which the gear *c'* moves, and hence helps to turn gear *a* in a direction opposite to that in which the driving gear *b* moves. The gears *d'* and *d* are duplicates of the gears *c* and *c'*, each pair transmitting a portion of the power when the lever is reversed. When the reverse spreader *h* is thrown out of engagement and the forward spreader *i* is thrown in, the same movement of the reverse lever serving to accomplish both operations, the clutch *f* grips the drum *e*, which is thereby caused to rotate with the driving shaft to which the clutch *f* is keyed, all the gears being locked together. The gears therefore have no relative motion, and the whole mechanism, including the propeller shaft, rotates at the speed of the driving shaft.

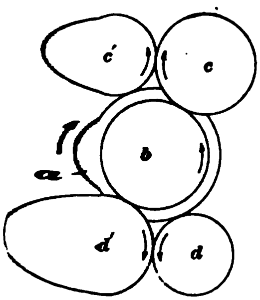


FIG. 8 (*b*)

9. A somewhat different type of reversing gear is shown in Fig. 9. The driving shaft a is connected directly to the propeller shaft b by the clutch coupling c in the position it

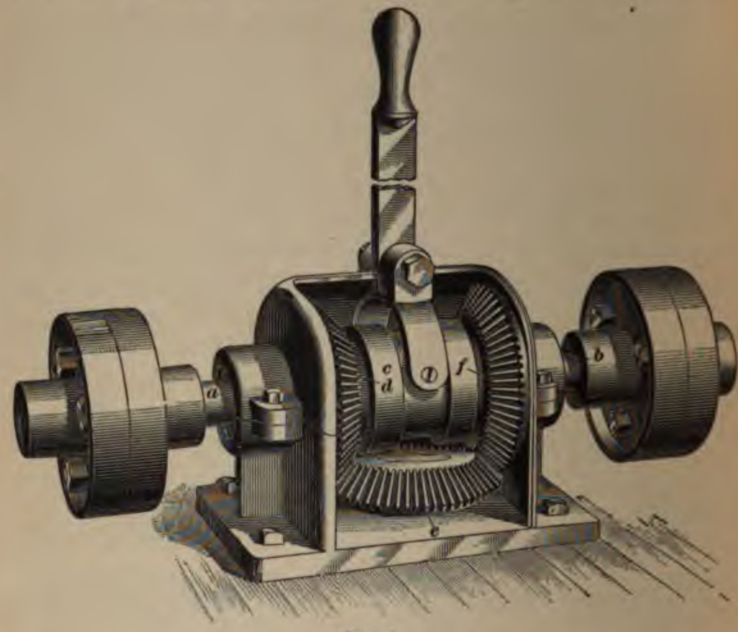


FIG. 9

now occupies. In this position the gears d, e, and f do not transmit power, but the gear f turns idly on the propeller shaft. By throwing the clutch coupling to the other side, however, the shafts are disengaged and the clutch holds the gear f rigidly to the shaft b, and the direction of rotation is reversed.

DIFFERENTIAL GEARS

PRINCIPLES OF OPERATION

10. Differential gears are composed of a set of four or more gears attached to the ends of two shafts that come together and are usually in line, so that both are rotated in the same direction; but if either meets with extra resistance it may rotate more slowly than the other or may stop altogether. These gears are used on the driving axles of automobiles. The axle is made in two parts, with a gear on the end of each where the parts come together; other gears mesh with both these axle gears and are driven from the engine by a sprocket and chain or by bevel gears and shaft. These gears turn the axle, but permit its two parts to turn in respect to each other so as to allow the automobile to go around a corner without causing the wheels to slide or skid. The rear wheels are each fixed to a half of the rear axle, and both receive power, hence it is necessary to allow one wheel to turn at a different speed from the other; this is done by the differential, or, as it is sometimes called, the *compensating* or *equalizing gear.*

SPUR-GEAR DIFFERENTIAL

11. A spur-gear differential is shown in Fig. 10 with the ends of the two shafts, carrying the gears *c* and *d*. The sprocket wheel *e* is driven from the engine by a chain, and is in turn fastened to a gear-case that carries a series of small gears *f*, *g*, arranged in four pair, each gear being mounted on its own axle. The two gears of each pair mesh together, and one is in mesh with gear *c* while the other meshes with gear *d*. By this arrangement both gears *c* and *d* are drawn in one direction, and yet they may turn with respect to each other when the resistance to the turning of one is greater than that of the other. When the

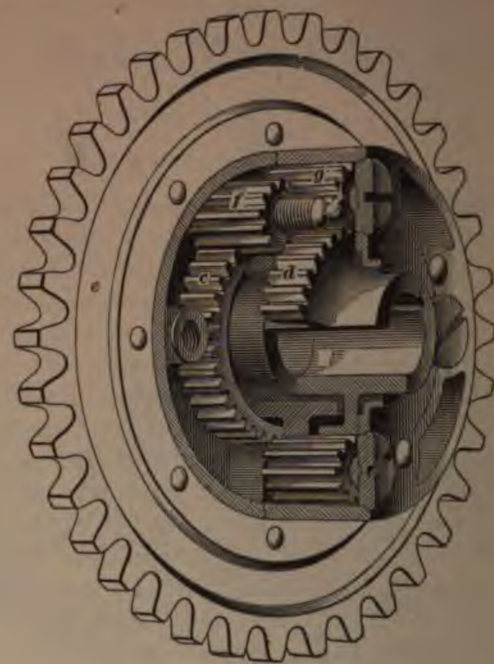


FIG. 10

resistance to the movement of gears c and d is the same, the four pair of small gears f, g do not turn on their axles but simply carry gears c and d around together.

BEVEL-GEAR DIFFERENTIAL

12. The two parts to a driving axle may also be permitted to turn independently of each other by means of a bevel-gear differential, as shown in Fig. 11. In this case the driving shaft from the engine carries the bevel gear a that meshes with the bevel gear b on the differential gear-case c. To the inside of the gear-case are fastened a number of bevel gears, as d, that are permitted to turn on the studs that hold them to the gear-case. These gears in turn mesh with the bevel gears e and f on the ends of the half axles. The principle on which the bevel-gear differential works is similar to

that for the spur-gear differential. When both gears meet with the same resistance, the small bevel gears *d* do not turn on their bearings; but when the movement of one of

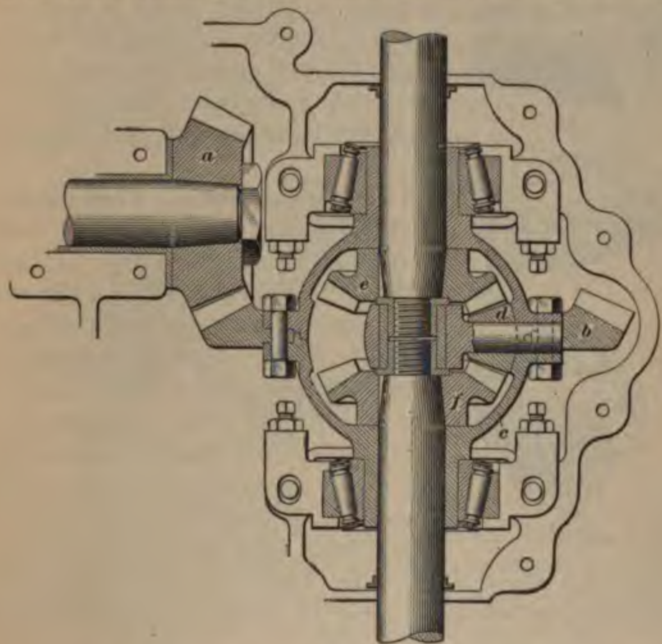


FIG. 11

the gears *e* or *f* is resisted more than that of the other it lags behind, causing the small bevel gears to turn on their axles sufficiently to cause the resistance to be equalized.

COUPLINGS, CLUTCHES, AND BRAKES

COUPLINGS

13. Plain Couplings.—Several plain couplings, such as are used on propeller shafts of motor boats, are shown in Fig. 12 (*a*), (*b*), and (*c*). The one shown in Fig. 12 (*a*) holds the two ends to be coupled together by means of setscrews through the holes shown in the sides of the coupling. In

the one shown in Fig. 12 (*b*), the ends are clamped by means of bolts, one end of the shaft being in one end of the coupling and the other in the opposite end of the coupling. In Fig. 12 (*c*) is shown the flange coupling, one-half of which is keyed to each end of the shaft so that the separate shafts are held together by means of bolts through both flanges.

(a)

(b)

(c)

FIG. 12

14. Compression Coupling.—A modified type of flange coupling, known as a *compression coupling*, is shown in Fig. 13 (*a*) and (*b*), (*a*) showing the separate parts and (*b*) the assembled coupling. In this coupling no keys are used, but a loose sleeve *a*, Fig. 13 (*a*), fits over the ends of the two parts of the shaft to be coupled; the sleeve is tapered on the outside toward both ends and has six slits, three from each end, equally spaced around the sleeve. The loose sleeve *a* is first slipped in place over the shaft and then the parts *b* and *c* are brought

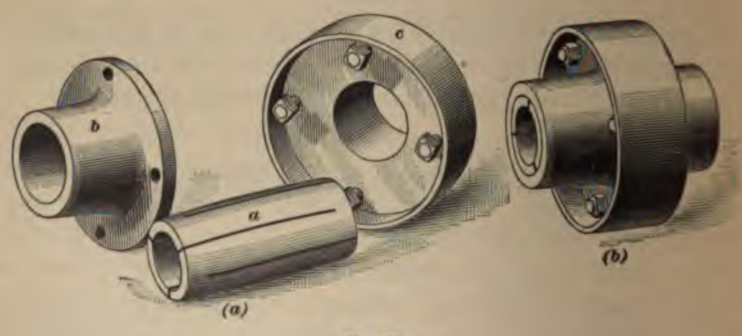


FIG. 13

together on the sleeve. They are drawn and held together by bolts, and the friction produced by the pressure of the

sleeve on the two parts of the shaft, owing to the taper on the sleeve, holds them together.

15. Universal Coupling.—It is often desirable to have the propeller shaft so constructed that one part may stand at an angle to the other. This may be done very conveniently by means of a **universal joint** or **coupling,** sometimes called a **crab claw,** shown in Fig. 14. The shaft *a* is connected to the shaft *b* by the coupling shown at *c*. Two forks

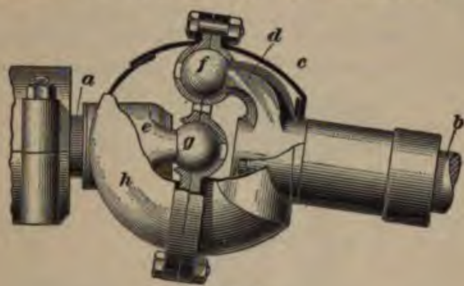


FIG. 14

d and *e* are connected to the shafts; on the ends of the forks are balls *f* and *g*, which turn in cups that are fastened to the casing *h*, which turns with the forks. Each fork is thus permitted free motion at right angles to its shaft. A coupling of this type permits the shafts to turn freely so that power can be transmitted through the two shafts at a slight angle almost as readily as through a continuous shaft.

When the power must be transmitted from one of two parallel shafts to the other, the two must be connected by a third, or intermediate, shaft with a universal coupling at each end. In order that the motion of the driven shaft may be the same as that of the driving shaft, the forks on the intermediate shaft must stand in the same plane.

CLUTCHES

16. Cone Clutches.—The clutches commonly used on the power-transmission mechanism of automobiles and motor boats may be divided roughly into three classes; namely, *cone*

clutches, *band clutches*, and *disk clutches*. They are designed to permit the engine to be disconnected from t transmission gearing, either while the gears are being shift or when the machine is to be stopped.

The **cone clutch** is provided with a cone-shaped memb attached to one part of the shaft, and a tapered ring or c into which it fits. When the cone is forced into the rin both shafts are held firmly together by the friction of t conical faces.

There are a number of modifications of this type of clut one of which is shown in Fig. 15. The flywheel *a* is fasten

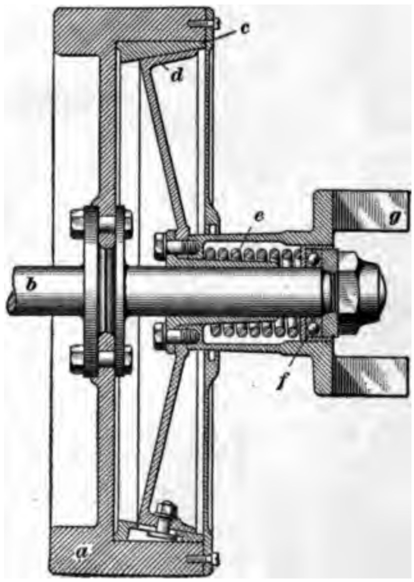


FIG. 15

to the shaft *b* by means of bolts through the web of the wheel. At *c* is shown an expansion ring into which the friction cone *d* fits. The helical spring *e* holds the cone against the expansion ring with the required amount of force. At *f* is a ball bearing that takes the end thrust when the cone is pulled away from the expansion ring. The arms *g* are coupled to the propeller shaft that turns with

the friction cone. Ordinarily, the two parts of the clutch are held together by the pressure of the spring, and when it is desired to disconnect the cone, as when the speed is being changed on an automobile, a foot-treadle is forced down so as to act on a fork and sleeve and pull the cone away from the expansion ring. As soon as the treadle is released the spring *e* forces the clutch into action again.

17. Band Clutch.—Another type of clutch known as the **band, or friction-ring, clutch** is shown in Fig. 16.

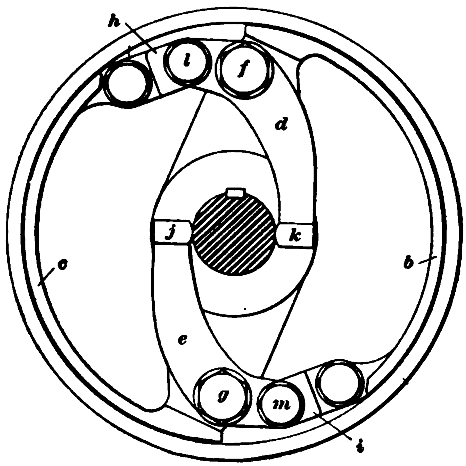


FIG. 16

The wheel, which is connected to one of the shafts, is shown at *a*, and the band or ring, which is connected to the other shaft, and which is made in two parts, is shown at *b* and *c*. At *d* and *e* are curved arms pivoted at *f* and *g*. The links *h* and *i* connect these curved arms to the parts *b* and *c* of the band. By means of a fork and tapered sleeve, not shown, the ends *j* and *k* of the arms are forced apart when the clutch is brought into use. This throws toward the shaft the ends *l* and *m* of the levers *d* and *e*, and brings the two parts *b* and *c* of the clutch ring in contact with the friction or driving surface of the wheel *a*, which is thereby forced to turn with the driving shaft.

18. Disk Clutch.—A clutch of the multiple-disk type is shown in Fig. 17. A two-arm spider *a* keyed to the shaft *b* serves to hold in place a number of metal disks *c*, between which are other metal plates *d* held on the sleeve *e* by means of a key *f*. The sleeve *e* is in turn keyed to the shaft *g*, and to it is screwed a ring *h* having three pair of lugs carrying three levers *i* with rollers *j* at their outer ends, as shown. The other ends of the three levers press against the plate *k* when the clutch is engaged by an inward movement of the collar *l*,

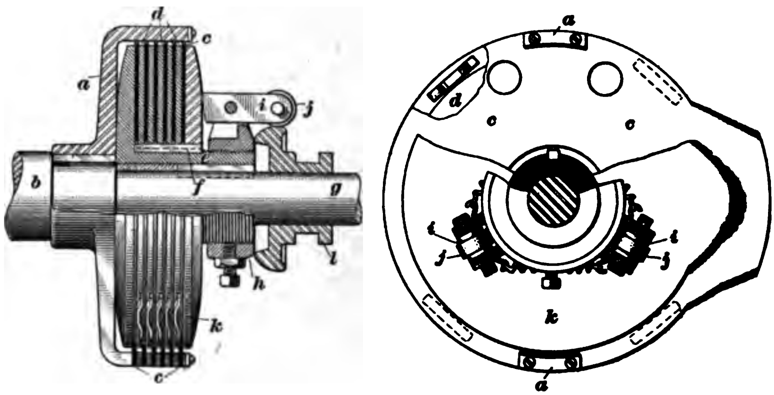


FIG. 17

the plate *k* being free to move along the key *f*. The disks *c* are free to move longitudinally on the arms of the spider *a* and also on the sleeve *e*, around which they rotate when the clutch is out of engagement; but the arms of the spider, fitting into slots in the disks, cause them to rotate with the shaft *b*. The plates *d* are free to move longitudinally on the key *f* in the sleeve *e*; and since the sleeve is keyed to the shaft *g*, it is evident that, when in engagement with the disks *c*, the plates *d* must cause the shaft *g* to turn with the shaft *b*. The disks *c* and the plates *d* run in an oil bath, obviating wear of the plates and disks. These are brought together forcibly by throwing the cone-faced end of the collar *l* against the rollers *j*, thereby causing the ends of the three levers *i* to press the plates and disks together with sufficient force to cause the shafts *b* and *g* to rotate as one shaft.

BRAKES

19. The power-transmission system of an automobile is usually fitted with one or more brakes. The most common arrangement is to have a brake on the propeller shaft and one on the hub of each of the rear wheels. The brake may be of the expanding type placed inside some wheel as a flywheel, or it may be on the outside of a wheel, in the form of a band. The band brake is often applied to the hubs of the rear wheels and is operated by means of a treadle. A rear-hub brake is shown in Fig. 18, with the hub at *a* and the brake band at *b*. The connecting-rod *c* from the treadle to the lever *d* tightens the brake by drawing the link *e* down and shortening the brake band *b*. The lug *f* is held from turning with the hub by the arm that extends from the axle casing to the pin *g*. Releasing the treadle allows the rod *c* and the lever *d* to move back and thus throw off the brake.

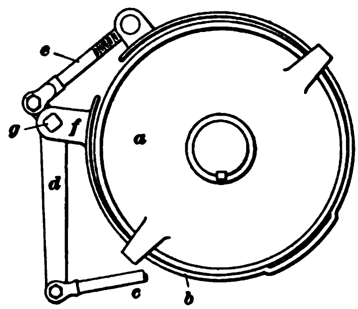


FIG. 18

STARTING AND GOVERNING DEVICES

STARTERS

HAND STARTER FOR AUTOMOBILES

20. The most common method of starting automobile engines is by means of a simple hand crank that can be connected to the engine shaft and by means of which the shaft can be turned by hand until a charge is drawn into the cylinder, compressed, and ignited. Some cranks are made so that they will disengage as soon as the engine starts, and also so that, should the engine explode a charge and start backwards, the backward motion, frequently called a *kick*, will not injure the operator. A crank of this type is shown in Fig. 19. The handle *a* is connected to the end of the long sleeve *b* by the pin or latch *c*, which is held in one of a number of equally spaced slots in the end of the sleeve by a spring inside the crank at *d*. The ratchet wheel *e* is fastened to the frame of the automobile and is thus held stationary, having an opening of sufficient size to permit the sleeve of the crank to be inserted and fitted to the crankshaft. The pawl *f* fits into the notches of the ratchet wheel.

FIG. 19

and is rigidly connected to the lever *g*. The pin *h* and the spring *i* hold the lever *g* against the pin *j*, which is fastened to the latch *c*, and also hold the pawl *f* down to the ratchet wheel. The slot *k* in the sleeve fits on a pin in the crank-shaft of the engine, so that as the crank is turned in the direction of the arrow it turns the crank-shaft, but it cannot turn the crank-shaft in the opposite direction. If the engine should kick backwards, the pawl *f* would be stopped by the teeth of the ratchet *e*, and in turning would raise the lever *g*, lifting the pin *j* and the latch *c*, thus permitting the sleeve *b* to turn freely without carrying the handle with it.

AUTOMATIC STARTERS FOR AUTOMOBILES

21. In Fig. 20 is shown a small hand air pump that is attached to the side of the car near the driver's seat. The

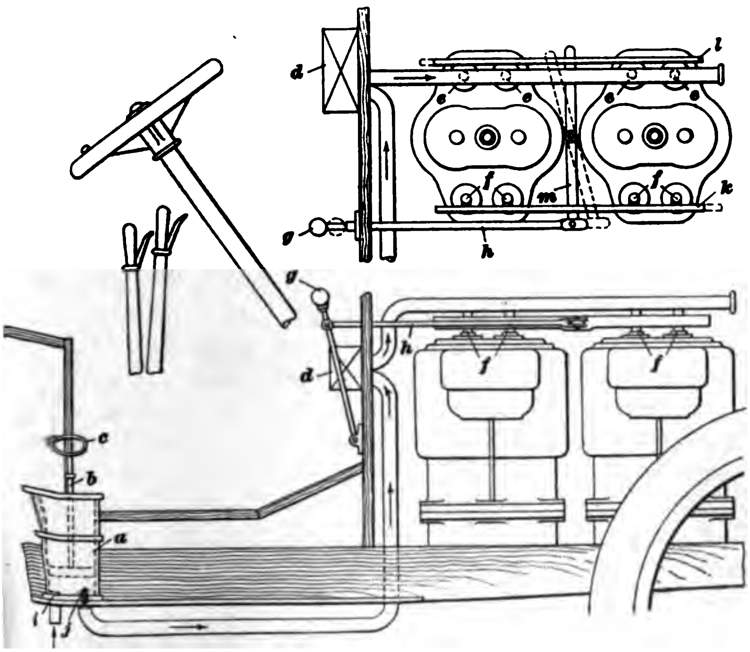


FIG. 20

cylinder *a* is of rather large diameter, the piston rod *b* carries a handle *c* of convenient size, and the pump is placed in the most convenient position for the driver to operate without leaving his seat. The object of the pump is to compress air for starting, the air passing over gasoline in the surface carbureter *d* on its way to the valves *e* through which the starting charge is admitted to the cylinders. To start the engine, the valves *e* and compression relief cocks *f* are opened by means of the operating handle *g* attached to the rod *h*, the driver gives the pump plunger a few strokes, and the air is driven through the carbureter *d* to the explosion chambers of the engine cylinders. The charge is then ignited and the engine started. Air for the compressor is drawn into the pump cylinder *a* on the up stroke through the flap valve *i*, and is expelled on the down stroke through the outlet valve *j*, which is seated by a spring, as indicated. Simultaneous operation of the relief cocks and charging valves is effected by connecting the rods *k* and *l* to the lever *m* attached to the rod *h*.

MARINE-ENGINE STARTERS

22. Marine gas engines are usually started by hand. Some four-cylinder marine engines, however, are equipped with air starting and reversing mechanism, one type of which is shown in Fig. 21. This mechanism consists of a hand bicycle tire pump, two check-valves, a priming cup, piping to the two after cylinders, and stop-cocks therein. A plain lubricator *a* is used as a priming cup, *b*, *b* are two check valves, *c* is the tire pump, *d* and *e* are stop-valves that are sometimes placed at *f*, *f*, and *g*, *g* are the two after cylinders, that is, the two cylinders toward the stern of the boat—of a four-cylinder engine. The priming cup is partly filled with gasoline, which is allowed to run into the base of the pump. The engine is turned over by hand until the piston has slightly passed the upper center and the igniter has snapped. The piston in the other cylinder will now have begun to start on its compression stroke. The valves

d and *e* are opened, and pressure is pumped up in the two cylinders. The valves are closed, and the igniter in the cylinder with the piston just past the upper or outer center is snapped by the finger, when, if the proportions of the charge in the cylinders are correct and all other conditions are right, the engine will start. The advantage of a compressed-air starting and reversing mechanism for starting the engine in either direction lies in its small size and

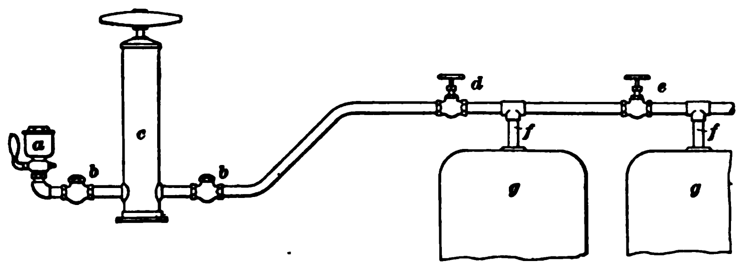


FIG. 21

low first cost. In operation, different sets of cams and usually auxiliary air valves are employed to control the movement of the engine. In six-cylinder engines, only three of the cylinders are equipped with the air attachments, the other three taking up their cycle of operation when the mixture ignites, whereupon the compressed air is shut off and the regular inlet- and exhaust-operating cams come into operation in place of the air-valve operating cams.

With some large engines, a smaller engine is sometimes employed to start the larger, the small one being disconnected as soon as the larger one starts.

GOVERNORS

AUTOMOBILE GOVERNORS

23. Automobile engines are controlled by manipulation of the throttle valve and the position of the spark, sometimes called the *spark lead.* More accurately, the control proper is accomplished by regulation of the throttle, and the spark advance is regulated to keep the ignition at its most advantageous point for developing the maximum power of the charges received.

The manipulation of the spark is sometimes employed to modify the speed of the engine, because, with the spark retarded to cause ignition to occur later than it should, the power of the motor is very materially reduced. This, however, is a most objectionable practice for several reasons: In the first place, it evidently wastes gasoline, because the same result as regards power may be obtained with smaller charges and an earlier spark. Second, the inflammation is so prolonged that it probably is not completed at the time the exhaust valves open, so that the valve seats are exposed to streams of gas still burning. This not only overheats the valves and is liable to warp them, but it soon burns and cuts their ground faces and their seats. Third, the motor is overheated and preignition of the incoming charge may result, producing explosions in the carbureter and intake pipe. It is, however, permissible to retard the spark to prevent racing, that is, running too fast, when the throttle is nearly closed and the motor is running light, with the car standing still.

24. Since automobile motors are operated under wide variations of speed and load, it follows that for correct action the throttle and spark cannot always be operated together For example, a rarefied charge, such as is obtained with the motor running at medium speed, with the throttle nearly closed, will burn comparatively slowly

and requires an advanced spark for its prompt combustion. Suppose, now, that the car is running at moderate speed under these conditions, as it may when descending a slight grade, or even on level ground. If a slight up grade is encountered, the operator will open the throttle to increase the power. Under such conditions the speed of the motor will probably not increase, but it will be found that the spark advance suitable for the previous conditions is too early for the increased charges. This will be indicated by the laboring sound and possible pounding of the motor, either of which sounds may be stopped at once by slightly retarding the spark.

If the throttle and the spark mechanism were positively connected, it would be impossible to advance the spark while closing the throttle, as was required for the first set of conditions, and to retard the spark while opening the throttle, as was necessary for the second set of conditions. Although having the two positively connected simplifies the operation of the car in the hands of the novice, and although it is undoubtedly satisfactory under some conditions, as for example when the car is speeded along a level road, it is not flexible enough to give the most favorable results in either speed or fuel economy.

25. A simple automobile governor acting on a throttle valve located in the intake pipe is shown in Fig. 22. The flyballs *a, a* are revolved about the engine shaft *b* and fly outwards against the resistance of the spring *c* under the action of centrifugal force. The flyballs move the sleeve *d* outwards as the speed of the engine increases and inwards as it decreases. The rocker *e* pivoted at *f* moves with the sleeve *d* and transmits its motion through the rod *g* to the throttle valve *h* in the supply pipe *i*.

26. Small engines are commonly controlled entirely by hand, there being no centrifugal governor on them. Almost all automobiles with four-cylinder engines of 16 horsepower or more have centrifugal governors, whose function is partly to prevent the engine from racing when

the clutch is released, and partly to facilitate the control of the automobile by making the engine semiautomatic in its speed regulation, thus relieving the operator of part of the

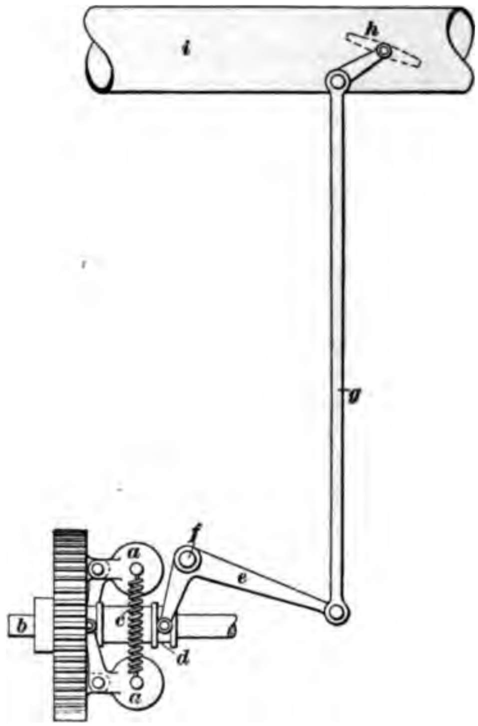


FIG. 23

attention to the throttle, otherwise necessary. When the centrifugal governor is employed, it is always arranged to be modified in its action by the operator. This may be accomplished in several ways, of which the simplest is to open or close the throttle forcibly against the resistance of the governor mechanism. This may be done by running a connection from the long upper arm of the governor lever to suitable controlling mechanism under the operator's hand. The usual connection would be a slotted link, attached to the governor lever so as to permit the governor

flyballs to approach each other but not to separate, and would therefore limit the degree to which the throttle was permitted to close.

27. A more elaborate arrangement than that shown in Fig. 22 is shown in Fig. 23. It has the special feature that the hand regulating device imposes no stress on the governor mechanism, and friction and wear due to this cause are eliminated. The flyballs *a* of the governor revolve around the engine shaft *b*, their outward motion being resisted by the spring *c*. The sliding collar *d* and governor lever *e* act on the throttle arm *f* through a slotted link *g*, and as the flyballs separate, this link is simply shifted to the left and

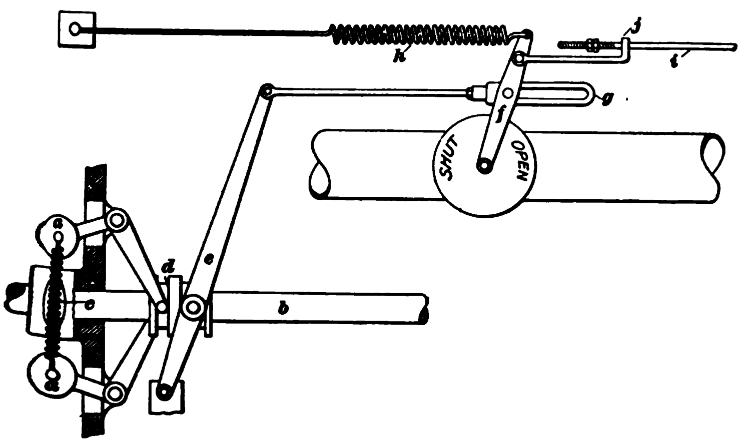


FIG. 23

the throttle is closed by the tension of the spring *h*. The hand regulation is effected through the rod *i*, which works freely in an arm *j* connected to the throttle arm, and has an adjustable nut and locknut at its end, by means of which the throttle may be pulled open against the tension of spring *h*. When the throttle is thus forcibly opened, the slot in the link *g* permits the governor mechanism to remain in its natural position, as determined by the speed of the engine. As *i* is rigidly connected to the hand control lever,

the effect is to limit the degree to which the throttle can close, this restriction being independent of the action of the governor. Consequently, if the rod *i* is pulled to the right as far as it will go, the throttle is held wide open.

MARINE-ENGINE GOVERNORS

28. Governors are not used on marine engines to any great extent. Several makers of engines up to 100 horsepower or more have never adopted them, or have discarded them after several trials. Small engines rarely have them, except when used for some special purpose. When governors are used they are almost always of the throttling type, similar in principle to those used on automobiles.

The governors in use are usually within the flywheel, or are mounted on the throttle valve and operated by a belt from the crank-shaft, and are of the centrifugal type.

They are quite convenient when using a reversing gear, but very many engines have been wrecked when too much dependence has been placed on the governor and it has failed to act, as, for instance, through the breaking of a belt or spring or a stud carrying the lever arm.

If the engine is of the automobile type with very light reciprocating parts, it gathers headway more rapidly than a heavy low-speed engine, and for this reason is much more likely to be wrecked should a governor fail to work properly.

It is an excellent plan to have a switch in the battery circuit convenient to the steersman, so that the current may be shut off should an emergency of any kind develop that would necessitate suddenly stopping the engine. Some engines are so installed that they may be handled from two or more parts of the boat, and in this case the danger referred to would be considerably lessened.

COOLING AND MUFFLING DEVICES

WATER-COOLING SYSTEMS

MARINE-ENGINE COOLING

29. Marine engines are cooled by the circulation of water through the water-jacket of the engine cylinder. A pump attached to the engine draws water through the bottom of the boat, sends it to the engine, and finally discharges it into the exhaust pipe, which is sometimes led under water, discharging through a special fitting, one form

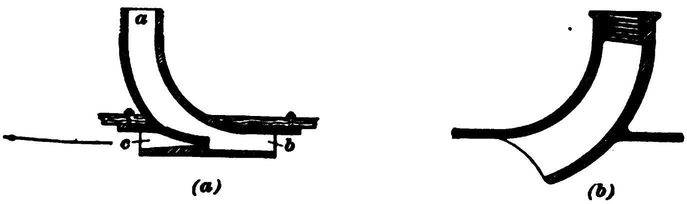


FIG. 24

of which is shown in Fig. 24 (*a*). The exhaust enters the fitting at *a* and leaves at *b*, under the water, the boat moving in the direction of the arrow. On account of the velocity of the boat, water rushes into the opening *c*, through the gradually reducing passage, into the exhaust pipe, and out with the exhaust at *b*. This arrangement tends to increase the velocity of the exhaust and reduce the back pressure on the engine.

Another form of exhaust nozzle is shown in Fig. 24 (*b*). This form resembles that shown in Fig. 24 (*a*), except that the passage *c* is omitted.

AUTOMOBILE-ENGINE COOLING

30. In automobiles, the circulating system is open to the atmosphere, and it is important that the water used for cooling should not be allowed to boil, because it would soon be exhausted. Since it is impossible to carry a large supply of water, it is necessary to use coolers, or **radiators**, as they are called, through which the water is circulated, and which have a large metal surface exposed to the air.

Owing to the considerable amount of power developed by many automobile engines, and the necessarily small amount of cooling water that can be carried to supply them, highly efficient means must be adopted for dispersing the heat as fast as it is received by the water. As the only way of accomplishing this, without the evaporation of the water, is to give the heat to the air by convection, it follows that the logical method of cooling the water is to spread it in as thin sheets as possible over metal surfaces exposed to free currents of air set up by the movement of the vehicle, by a suitable fan, or by both.

31. In a few makes of cars of moderate power, gravity circulation alone is relied on to keep the water in motion. In this case the bottom of the radiator should not be lower than the bottom of the water jacket, and the top of the radiator should be as much higher than the top of the jacket as conditions will permit. The arrangement of the piping for gravity circulation is shown in Fig. 25. The vertical radiator tubes *a*, *a* are connected at top and bottom by manifolds *b*, *c*, or chambers with suitable connections for the pipes. The water leaves the top of the water-jackets *d*, *d*, enters the manifold *b*, descends through the tubes *a* to the lower header *c*, from which it flows back to the bottom of the jacket. As the water cools in the tubes *a*, *a*, it descends; and as it becomes heated in the jackets *d*, *d*, it rises; thus causing a continuous circulation. As it is essential that the return pipe be filled with water (else the cir-

culation would at once stop), it is customary to make the top manifold *b* large, as illustrated, forming a small tank

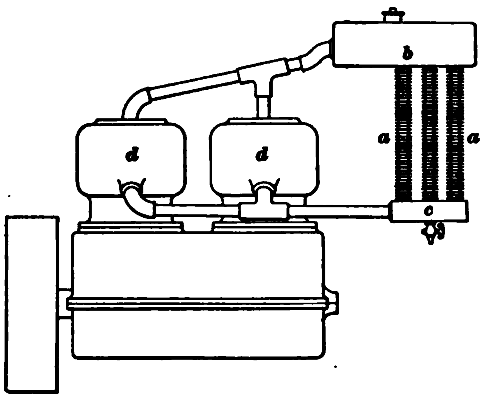
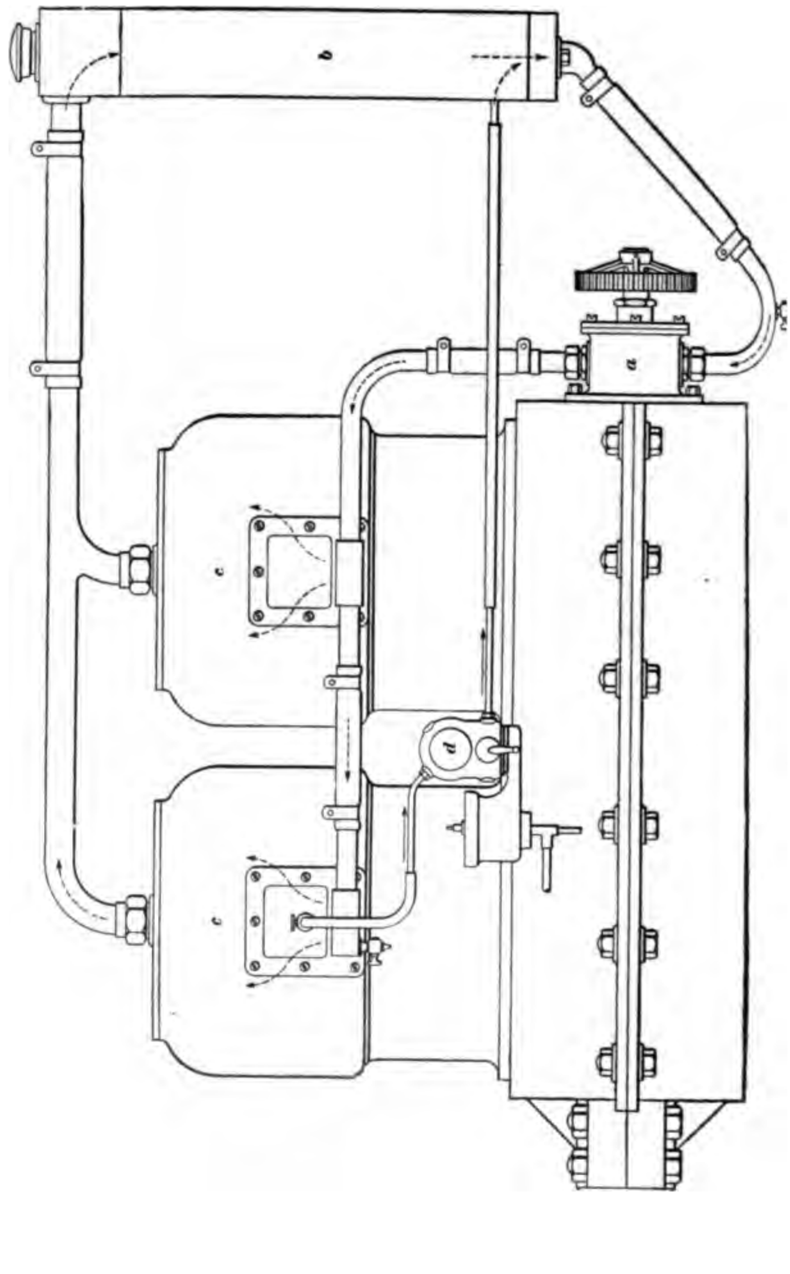


FIG. 25

containing a couple of gallons or so of water that will take some time to evaporate.

32. In any cooling system where the supply of water is limited, it is very essential that the movement of the water shall be rapid, and this means that there will be a difference of only a few degrees between the temperature of the water entering and that leaving the radiator. With so small a difference in temperature, and therefore in density, the impulse toward circulation in the gravity system is very small, and it is of first importance that the pipe connections between the jacket and radiator shall be very large, short, and devoid of sharp bends. In fact, it is not uncommon to use two or even three connections from the radiator to the bottom of the jacket, in addition to making the upper connections as large as possible.

33. In the majority of cars, gravity circulation is not relied on, either because it is not convenient to make the water connections sufficiently short and direct, or because the motor rises too high in the frame or is of too high power to be cooled in this way without employing a radiator of


b
a
c
d
c

undue size. Consequently, a circulating pump is usually employed.

A cooling system of this type is shown in Fig. 26, with the circulating pump located at *a*, the radiator at *b*, the engine water-jackets at *c*, *c*, and the carbureter at *d*. The water circulates through the pipes in the direction indicated by the arrows. It will be noticed that the carbureter is surrounded by a water-jacket, through which a small amount of water is circulated to warm it, the water passing to the radiator, where it mixes with the other water as it goes to the pump.

RADIATORS

34. Types of Radiators.—Radiators are usually made of thin metal with as much surface exposed to the air as possible, and they are arranged so that the air can circulate easily through them. Four forms of radiators are shown in Fig. 27 (*a*), (*b*), (*c*), and (*d*). The first, Fig. 27 (*a*), consists simply of a zigzag coil of copper tubing, on which are soldered a large number of thin flanges that increase the surface available for contact with the air. The one shown in Fig. 27 (*b*) is quite similar to that shown in Fig. 27 (*a*), but somewhat more complete, in that it has headers at the ends to which the flanged tubes are connected. The whole arrangement is enclosed in a sheet-metal casing having the outline of the automobile front. The one shown in Fig. 27 (*c*) consists essentially of top and bottom headers connected by a large number of thin flat tubes, crimped into zigzag shapes and placed vertically as close together as possible. In this way the water is divided into a large number of thin sheets contained in passages between thin metal walls, through which the heat of the water passes rapidly to the air drawn through them by the speed of the vehicle, aided usually by a suction fan just behind the radiator. Circulation is generally maintained by a pump, and the water enters the top of the radiator from the water-jacket, and goes out from the bottom to the pump and thence to the bottom of the jacket.

Fig. 27 (*d*) shows the back view of a type of radiator that consists of a shell with front and back tube plates into which are connected a large number of small horizontal tubes.

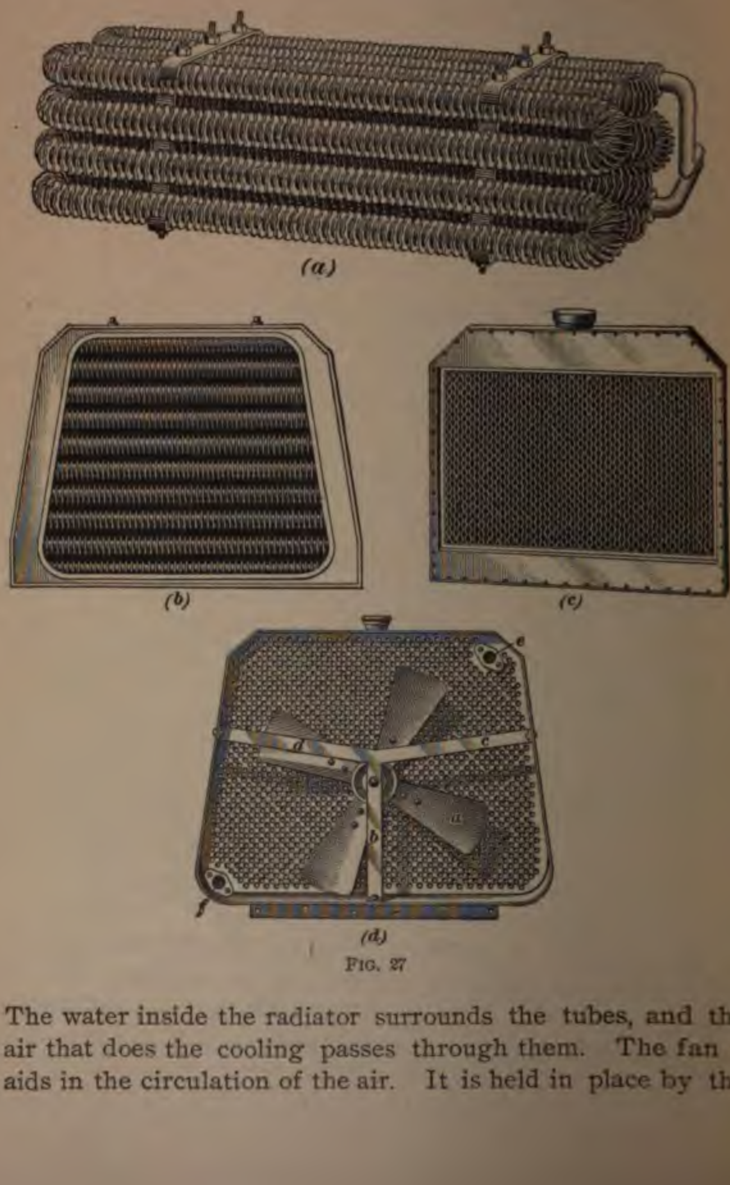


FIG. 27

The water inside the radiator surrounds the tubes, and the air that does the cooling passes through them. The fan *a* aids in the circulation of the air. It is held in place by the

three braces *b*, *c*, and *d*. The water enters the radiator at the upper right-hand corner through the connection *e*, and leaves through the opening *f* at the lower left-hand corner.

35. Removal of Scale From Radiators.—Owing to the narrowness of the water spaces in all forms of radiators, it is extremely desirable to keep them as free as possible from deposit and sediment of all sorts. On general principles, it is well to empty and wash the radiator occasionally, and in regions where the well and spring water is hard, rain water only should be used when it can be had. The use of hard water has the result, if the water gets hot, of precipitating in the jacket or radiator a scale exactly like that which forms in boilers. Even if the radiator is of the tubular type, this scale is objectionable because it interferes with the free transfer of heat from the water to the air.

Carbonate of soda, or common washing soda, is used for the removal of scale from radiators. It breaks up the hard deposits of scale into a powder or sludge, which can easily be removed by subsequently flushing out the radiator and piping thoroughly with water.

The water in the circulating system is drawn off and measured, care being taken that none is left in the pockets to dilute the soda solution. The solution is made in the proportion of 2 pounds of soda crystals to 1 gallon of water. The circulating system is entirely filled with this solution, which is allowed to remain all night. After drawing it off in the morning, a hose is connected and a good stream of water driven through at the best obtainable water pressure for some time, or until the water comes off clear.

CIRCULATING PUMPS

36. Types of Circulating Pumps.—Of the various types of circulating pumps, by far the most common, and in some respects the most efficient, is the **centrifugal pump** shown in Fig. 28. In this pump the only moving part is a bronze or aluminum disk *a*, keyed on a shaft *b*, and on

one face are cast blades *c*, *c*, which may be radial, as shown, or bent backwards. The shaft carries the disk *a* at one end, and works through a stuffingbox to prevent leakage. The water enters from the opposite side of the pump through an opening indicated by the dotted circle *d*, but which is on the side toward the observer, so that the water as it enters the pump meets the blades *c*. The water so entering is caught by the blades and thrown outwards by centrifugal force, being expelled at *e*. It is not necessary that either the disk or the blades have a water-tight fit in the casing, since the pump simply establishes a difference in pressure between the points *d* and *e*, but does not positively force the water. Consequently, if the flow is obstructed for any reason, the pump can still be revolved without injury to itself. Moreover, this type of pump does not lose its efficiency through wear. The pump is run at quite a high speed, generally about twice the speed of the engine; and if the resistance to circulation is not too great, it will throw quite a large stream of water. It is usually mounted on the crank-case of the engine and geared to the cam-shaft or to the two-to-one pinion.

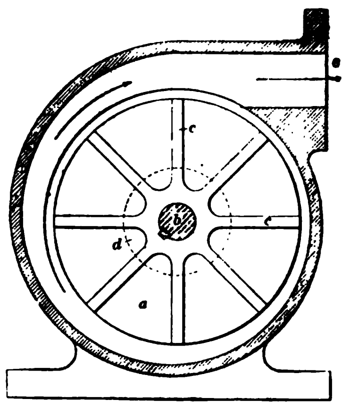


FIG. 28

37. A type of pump used to some extent for circulating purposes on automobiles is shown in Fig. 29. It is called a **gear-pump**, and it operates equally well in either direction. One of the two gear-shaped pump members *a* is driven by a shaft, and it rotates the other with it. If the direction of rotation is that shown by the arrows, the water will enter at *b*, and pass out at *c*, being carried around by the outer teeth *d*, *d*, and *e*, *e*, and expelled as the teeth come together. The particular pump shown has grooves *f*, *f* in the sides and tips

of the teeth, which, it is claimed, prevent to a large extent leakage past the teeth, and thereby increase considerably the efficiency of the pump.

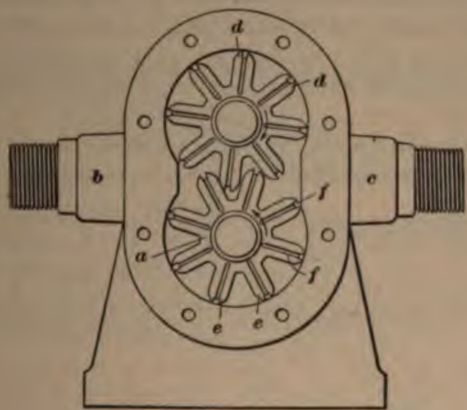


FIG. 29

38. Another type of pump is shown in Fig. 30. It consists of a cylindrical barrel *a* revolving eccentrically in the

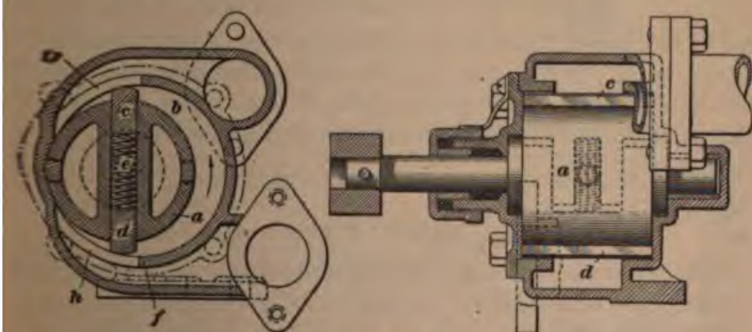


FIG. 30

chamber *b*. The shaft on which *a* turns is central with *a*, and the water is moved by the two blades *c* and *d*, pressed outwards by the spring *e*. The action of the pump depends on the motion of the blades *c* and *d* in the chamber *b*. Suppose the barrel *a* to be in the position shown and rotating in

the direction of the arrow until *d* has covered the edge *f* of the intake port; the water in front of the blade *d* will then be driven before *d* and out by the port *g*. Meanwhile, as soon as *d* has covered *f*, water is drawn into the space *h* behind *d* until *d* has nearly reached the position of *c*. This operation is repeated by the two blades, thus producing an almost continuous flow of water.

39. Circulation Pressure Gauge.—In order that the operator of an automobile may know whether or not the cooling water is circulating properly, a pressure gauge such as is shown in Fig. 31 is placed in the piping circuit. The gauge, which is frequently styled a **telltale,** is usually attached to the dash in such a position that it may readily be seen, the pressure created by the pump and registered by the gauge in ounces per square inch giving some idea as to the velocity with which the water is passing through the circulating system. If the gauge fails to register, it is evident that no water is flowing through the piping.

FIG. 31

MUFFLERS

40. Automobile and marine mufflers are generally very similar in construction, except that the marine types are often water-jacketed. Especially in automobile types, it is desirable that they be as light in weight as they can be made and do the muffling properly. A muffler of this type, in which the gases are deflected by a series of conical baffle plates, is shown in Fig. 32. The exhaust gases enter through the pipe *a*, flow into the central tube *b*, and a small portion passes out through the opening in the nozzle *c* to the outlet pipe *d*.

The velocity of the gas through the nozzle creates a partial vacuum in the chamber *e*. The opening in the nozzle being small, a portion of the exhaust gases flows around the end of the tube *b* to the chamber *f*. The partial vacuum in *e* draws the gases through the baffle plates *g*, one being perforated

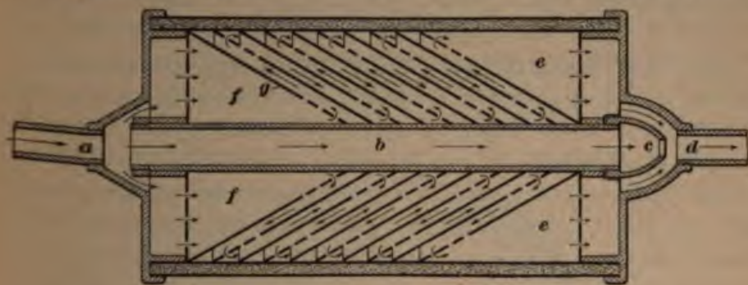


FIG. 32

near the center, and the next near the outside, so that the gases move in the direction of the arrows. The body of the muffler is composed of two steel cylinders, with asbestos packed between them, and closed at the ends by flanged heads. This muffler does not create an excessive back pressure on the engine, and reduces the noise considerably.

41. Another type of muffler is shown in Fig. 33. The gases enter at *a*, pass to the opposite end through the perfora-

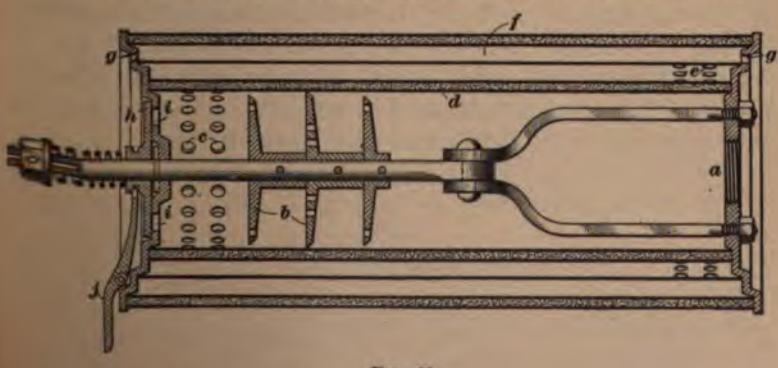


FIG. 33

tions, and around the ends of the baffle plates *b* and through the openings *c*. They then pass back outside the cylinder *d*,

through the openings *e* in the cylinder *f*, and finally out through the openings *g*. A relief valve *h* is held in place against the openings *i* by a spring. When the back pressure becomes excessive the valve opens, or it may be opened by a treadle near the driver, the treadle operating through a rod attached to the lever *j*.

42. Two forms of mufflers for marine engines are known as the *wet* and *jacketed mufflers* or the construction may represent a combination of both of these types. In the **jacketed muffler,** water from the cylinder water-jacket outlet is allowed to circulate around the outside of the muffler, to assist in cooling the gases and thereby reducing their volume. The **wet muffler** is one in which all or a part of the exhaust water from the water-jacket is discharged into the engine exhaust, where it is turned into steam, cools the exhaust gases, and combines with them, increasing their density and sluggishness, and thereby muffling the exhaust. The water from a jacketed muffler may be diverted into the exhaust itself, to further reduce the sound of the exhaust, this being the combination system above mentioned.

Muffling a well-designed engine results in more or less back pressure in the exhaust, and as a result the products of combustion are not so thoroughly removed from the explosion chamber, with a resulting loss of efficiency. It is for this reason that many marine engines are but slightly muffled, the increased noise not being quite so objectionable as it would be in an automobile used in the streets.

SCREW PROPELLERS

43. Types of Propellers.—The screw propeller is a very important part of the power equipment of a launch or motor boat. The rotary motion imparted to the crank-shaft by the gas engine inside the boat is given to the propeller outside the boat, and by its action on the water the boat is propelled forwards or backwards. Motor boats are seldom run backwards for any great distance, the backward motion being principally used when getting away from a wharf or dock, when stopping quickly, or when turning in a small space. The boat always moves more rapidly forwards than backwards, with the same expenditure of power.

FIG. 34

Figs. 34 and 35 show two forms of propellers. Fig. 34 has a very wide blade near the end, while Fig. 35 has the greatest width at a point about one-third the distance from the end of the blade. Propellers are also made with two and with four blades; when made with two blades they are opposite, or 180° apart. The blades on a four-bladed propeller are equally spaced around the hub.

As the propeller turns in the water, its motion is resisted by the water, and this resistance increases with the speed of the propeller; besides, when a propeller turns very rapidly, it churns the water without increasing the speed of the boat. The speed limit of propellers seems to be reached in practice at about 800 revolutions per minute; it is probable that,

at speeds in excess of 800 revolutions per minute, even in very light boats, any increase in power at the engine is more than counterbalanced and neutralized by propeller losses. In heavy, or working, boats, the loss of efficiency at high speed is very much greater than in light boats. It has been observed that, in heavy head winds, working boats that make but little progress with the engine running at 350 revolutions per minute will do considerably better at 20 per cent. less speed.

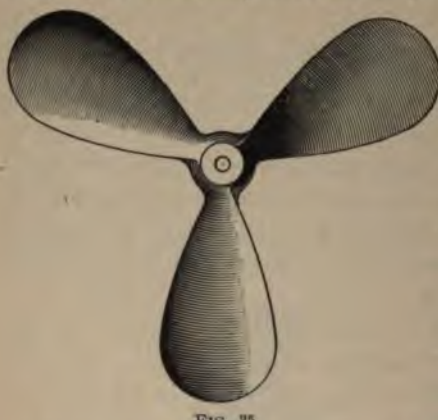


FIG. 35

44. Pitch of Propeller.—The **pitch** of the propeller is the axial, or longitudinal, distance through which the propeller would force the boat, in one revolution, if there were no resistance. The amount the resistance reduces the longitudinal motion of a boat is called the **slip.** The pitch of a propeller is measured in the same way that the pitch of a screw is measured. If a screw has eight threads in 1 inch of length, the distance from one thread to the next is $\frac{1}{8}$ inch and the pitch is consequently $\frac{1}{8}$ inch; that is, in moving a point around the screw thread once, it advances $\frac{1}{8}$ inch along the axis. In the three-blade propellers shown in Figs. 34 and 35, it will be noticed that there are three distinct surfaces, all of which have the same pitch, and that these surfaces resemble a portion of a screw with three threads.

The diameter of a propeller is the diameter of a circle described by the tip of the longest blade. If the circumference of the circle of any point on a blade is laid off on a straight line, the pitch laid off at right angles at one end, and the triangle completed, it will form a right triangle, as shown in Fig. 36. Let the base *a b* represent the circumference

of a circle described by a point on the tip of one of the blades of a propeller; *b c*, the pitch or distance advanced along the axis in one revolution; and *a c*, the line completing the triangle. The line *a c* then represents the direction

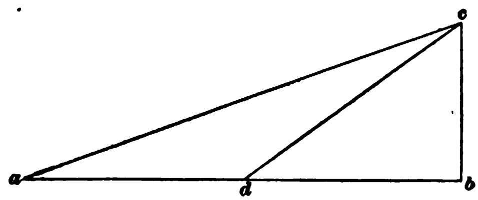


FIG. 36

of the face of the propeller blade, and the angle *b a c* is called the *angle of advance*. The circumference for a point one-half the distance from the center of the axis to the tip of the blade is one-half as long as the circumference for the point at the tip. Let the point *d* be located, on Fig. 36, midway between *a* and *b*; then, if the pitch is the same, the angle of advance *b d c* is greater than the angle of advance *b a c*.

45. A propeller with the same pitch for all points of the blade is said to have **uniform,** or **true, pitch.** A propeller blade has **increasing,** or **expanding, pitch** when the pitch increases from the axis to the tip of the blades, and **decreasing pitch** when the pitch at the axis is greatest and it decreases toward the tip of the blade. **Compound pitch** is any combination of pitches. The propeller might have true pitch at some parts, and increasing or decreasing pitch or both at other parts.

Fig. 37 shows, diagrammatically, the difference in the angle of advance for different points of blades having true, increasing, and decreasing pitches. Let the length of the line *a b* represent the circular distance traveled by the tip of the blade in one revolution, and let *b c* represent the pitch of the blade at the tip. Let the points *d*, *e*, and *f* be at three-quarters, one-half, and one-quarter the distance *a b* from *b* and on the same blade. Then, for true pitch the length *b c* is the pitch for all these points, and the lines drawn from *c* to *f*, *e*, *d*, and *a* make decreasing

angles with the line *a b*, that is, for a propeller of uniform pitch, the angle of advance decreases from the axis toward the tips of the blades. If, on the other hand, lines are drawn from *d*, *e*, and *f* parallel to *a c*, as *d g*, *e h*, and *f i*, making the same angle with *a b*—that is, if all points of the propeller blade have the same angle of advance—the pitch increases from the

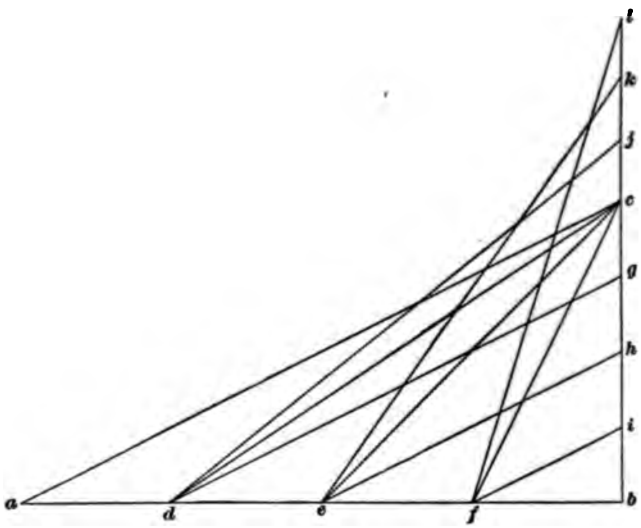


FIG. 37

axis to the tips of the blades. The pitch at one-quarter the distance from the axis to the tip is *b i*; at one-half it is *b h*, at three-quarters it is *b g*; and at the tip, it is *b c*. Propeller blades having such angles would be said to have *increasing pitch*.

Continue the line *b c* beyond *c*, and lay off the points *j*, *k*, and *l*, and draw the lines *d j*, *e k*, and *f l*. When these lines represent the angles of the faces of the blades at different points, the pitch from the point *f*, where it is *b l*, decreases toward the tip, where it is *b c*. Consequently, such a propeller would be said to have *decreasing pitch*.

46. Measuring Pitch of Propeller.—In practice, the pitch of a propeller may be found quite closely in the manner illustrated in Fig. 38. Take a piece of joist or lath *D*, which should be as straight as possible, and place it so that

it touches one of the blades at any distance, as b, from the axis $A\ B$, taking care to hold it parallel with the axis. Next take a carpenter's square, shown at E, and place it on the lath and against the blade, so that the point at which the square touches the blade will be the same distance from

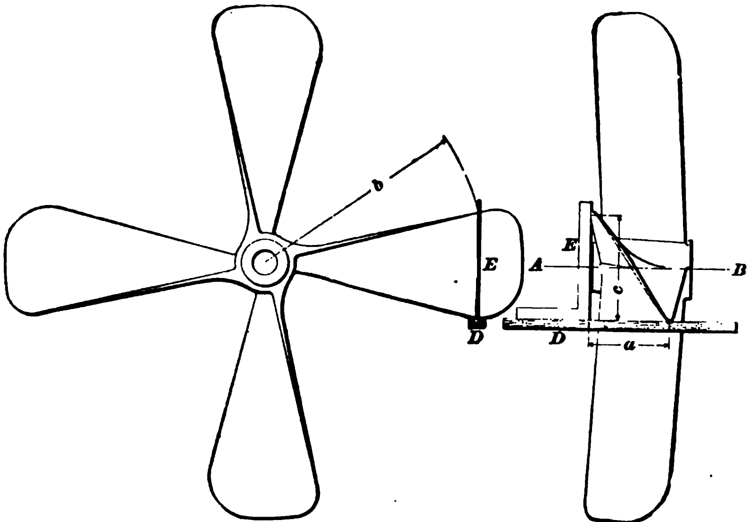


FIG. 38

the axis as is the lath. Measure the distances a, b, and c—a being the distance from the square to the point at which the lath touches the blade, and c the distance from the point at which the square touches the blade to the lath. Then the distance c is to the distance a as the circumference at this point is to the pitch. Expressed as a formula, the pitch is,

$$p = \frac{6.2832\,a\,b}{c}$$

where p = pitch of blade;
a = measurement taken along axis;
c = measurement at right angles to a
b = radius where pitch is taken.

EXAMPLE.—If the distance a is 10 inches, b $12\frac{5}{8}$ inches, and c 20 inches what is the pitch?

SOLUTION.—Applying the formula,

$$p = \frac{6.2832 \times 10 \times 12.625}{20} = 39.66 \text{ in., or, say, } 40 \text{ in. Ans}$$

47. It often becomes necessary to measure the pi
a propeller accurately, and the only manner in which it
done is by drawing two profiles of one of the blades. To

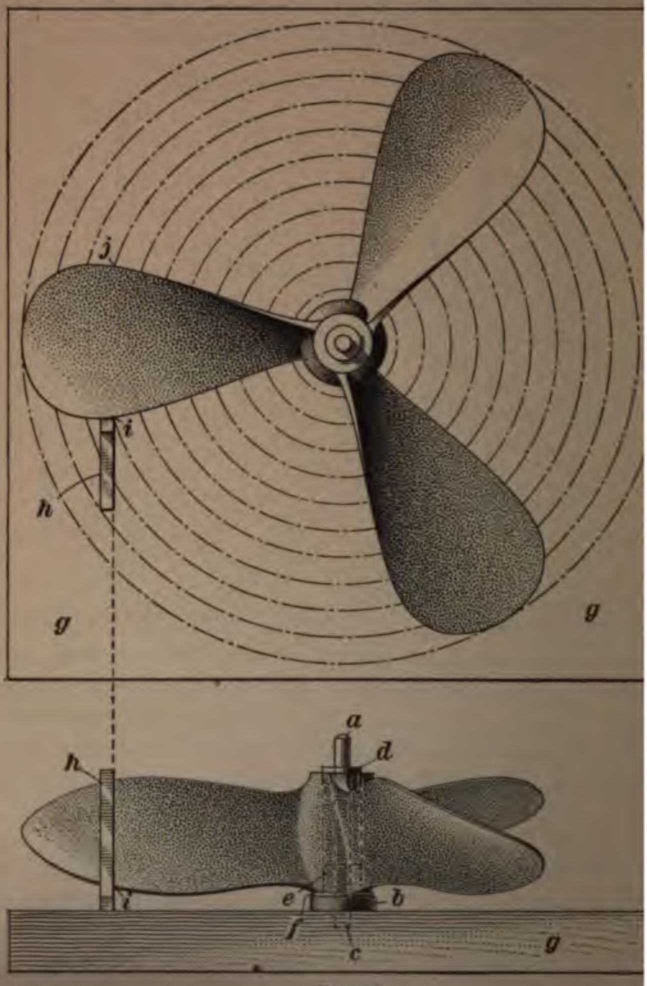


FIG. 39

the profiles, mount the propeller on a steel mandrel, as
in Fig. 39, and take the necessary measurements. The
drel a may be ½ inch in diameter, and long enough to c

through the wheel, with a round shoulder at *b* 2 inches in diameter, and an extension *c* ½ inch in diameter and ½ inch long. Two round hardwood tapered bushings *d* and *e* should fit the two ends of the hole in the propeller, and the mandrel inserted so that the wheel shall revolve at right angles to the mandrel. It may be necessary to add washers at *f* to

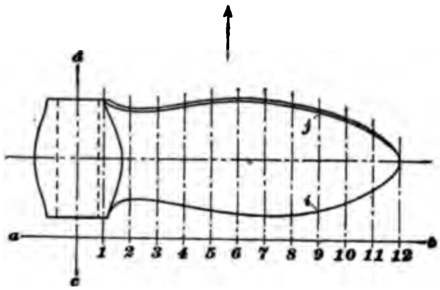


FIG. 40

allow the front or cutting edge of the wheel to be above the lower surface of the shoulder *b*. The mandrel should then be set into a drawing board *g*, on which are circles concentric with the mandrel, as shown. A line *a b* can be drawn as shown on Fig. 40, the axis laid off at *c d*, and lines drawn parallel to *c d* and spaced the same distance apart as the circles in Fig. 39. Then, by taking a square, as shown at *h*, the height of the lower side of a blade can be measured as shown at *i*, and this distance laid off on the corresponding line, as shown at *i* in Fig. 40. Then the square can be set on the other side of the blade on the same circle, the highest point measured as at *j*, Fig. 39, and laid off as shown at *j* in Fig. 40. If the angle of the square is set carefully on the circle, the point where it touches the circle marked, and the process repeated on both sides of the blade for each circle, a line can be drawn through these points, giving the end view as shown in

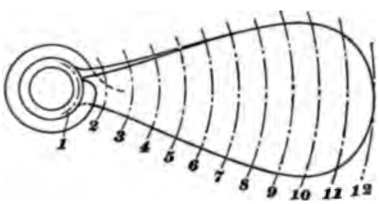


FIG. 41

Fig. 41, in which twelve measurements are taken. Having done this, the pitch can be calculated along any of the twelve circles by the formula in Art. **46,** taking the lengths of the arcs in Fig. 41 to represent *c* of the formula, the lengths of the corresponding straight lines in Fig. 40 to represent *a*, and the distances of the circles from the center to represent *b*.

When it is desirable to get increased blade area without increasing the width of the blades and making them correspondingly stronger, it is customary to use three or four blades.

The heavier the boat and the slower the engine speed, the greater the blade surface should be; while the lighter the boat and the higher the engine speed, the less the blade surface required, other conditions being the same.

48. Propeller Blades.—The **driving surface** of a propeller is usually the flat side of the blade that pushes the water astern, while the **crowning surface,** or **front,** is the part that draws the water toward the propeller.

The **cutting edge** is the part of the propeller blade that first enters the water when driving the boat ahead.

The **projected area** of the blades is the surface that forces the water back, and is measured at right angles to the direction of motion of the water. Fig. 40 shows a profile of a propeller blade taken at right angles to the shaft, while Fig. 41 shows a profile in the direction of the shaft. The area of Fig. 41 multiplied by the number of blades would be the **projected area** of the propeller surface, while the **developed area** would be the entire driving surface of the blades, usually called the **blade surface.**

The accepted form of blade surface to give the best results is what is known as a **warped surface.** In some one direction on such a surface, straight lines can be drawn, but to the eye, and by the application of a straightedge in any other direction, it has a slightly dished or concave surface.

49. Slip of Propeller.—The **apparent slip** of a propeller is the difference between the actual speed of the boat

with reference to some fixed point on shore and the speed at which the propeller would cut ahead, or travel through the water, without resistance or slip.

The apparent slip, often called simply the *slip*, is generally used in determining the action of the propeller. To test a propeller on a boat, in order to determine its apparent slip, its action should be observed when running the boat over a measured course. This may be done before or after the pitch of the propeller is measured. The number of revolutions of the engine should be recorded carefully, with the length of time to cover the course. The boat should be driven at a maximum speed, and if there is a known current its velocity should be added when running against the current and subtracted when running with the current. The engine should then be slowed a little, and the revolutions and time again recorded. These results should be figured out carefully and tabulated somewhat as follows:

COURSE $1\frac{3}{8}$ MILES, OR 7,260 FEET, PITCH OF PROPELLER, 40 INCHES

Revolutions Per Minute	Mean Time		Actual Speed Per Hour Miles	Speed Per Hour with No Slip Miles	Slip Per Cent.
	Min.	*Sec.*			
302	8	38	9.556	11.439	16
278	9	0	9.167	10.530	13
240	10	10	8.000	9.091	12
204	12	5	6.827	7.727	12
180	13	40	6.037	6.818	11

The speed per hour can be computed by using the formula

$$x = 60\frac{b}{a} \qquad (1)$$

in which a = time, in minutes, elapsed in traveling over the course;

b = length of course, in miles;

x = rate of speed, in miles per hour.

Thus, at 180 revolutions per minute, the speed in the table, taking $13\frac{3}{4}$ minutes as the time to travel $1\frac{3}{8}$ miles, would be $x = 60 \times \frac{1\frac{3}{8}}{13\frac{3}{4}} = 6.037$ miles per hour. Knowing the pitch of the propeller, and the number of revolutions per minute, the speed with no slip can be calculated by the formula

$$s = \frac{np}{1{,}056}, \quad (2)$$

in which s = speed with no slip, in miles per hour;
n = number of revolutions per minute;
p = pitch of propeller, in inches.

EXAMPLE.—If the pitch of a propeller is 40 inches, and the number of revolutions per minute is 180, what is the speed with no slip?

SOLUTION.—Applying formula 2:

$$s = \frac{180 \times 40}{1{,}056} = 6.818 \text{ mi. per hr. Ans.}$$

The difference between the cutting ahead and the actual speed is the slip, which in the example just given is $6.818 - 6.037 = .781$ mile, the rate of slip being the percentage .781 is of 6.818, which is 11.45 per cent. The table shows that the slip increases with the speed of the engine—a natural result.

50. Increasing the blade surface of a propeller, leaving the pitch and diameter the same, will reduce the effective power of the engine and the percentage of slip; while decreasing the blade surface will increase the effective power by reducing the resistance, the slip being increased. Increasing the pitch or reducing the diameter of the propeller will increase the percentage of slip, but will also increase the effective power of the engine; while reducing the pitch or increasing the diameter of the propeller will reduce the percentage of slip and decrease the effective power of the engine.

Whether the speed of the boat will be helped by decreasing the blade surface and increasing the pitch, or vice versa,

can be determined only by trial, there being so many combinations of conditions that the best designers of propellers frequently fail to obtain satisfactory results. By making an analysis of the propeller, pitch, blade surface, etc., and studying the results of tests, it is frequently possible to improve the speed of the boat by change of propellers, but such a change should not be made by guess. Propeller experiments are quite likely to be expensive.

When the pitch of a propeller is increasing or decreasing it is difficult to measure, and it is customary in that case to measure the pitch at a point one-third of the distance from the end of the blade to the center of the shaft, and the pitch thus measured is usually referred to as the **mean pitch.** Or, the pitch may be measured at several equidistant points each side of the center of the blade, and a mean of the measurements taken as the mean pitch.

51. Reversing Propellers.—In some cases it is found expedient to use reversing or feathering blade propellers. The blades may be feathered or the angle at which the driving surface strikes the water may be so changed that the water is driven ahead instead of astern, without reversing the direction of rotation of the propeller shaft. Midway between the ahead and the astern position is a neutral zone in which an equal power in both directions is exerted, with no effect on the boat in either direction. There is usually but one position of the blades that approximates true pitch, and on this account there is a considerable amount of power lost in their use, unless they are very carefully designed and specially built.

A sleeve sliding on the shaft and connected to the blades themselves, often within an enlarged hub, or attached to it and operated by means of a lever or hand wheel inside the hull, is sometimes used to control the position of the blades. Such an arrangement is shown in Fig. 42 (*a*). The propeller blades are shown at *a*, *a*, the outside stuffingbox at *b*, the stern bearing at *c*, the sliding sleeve at *d*, the inside stuffingbox at *e*, and the reversing lever at *f*. One of the blades

separate from the device is shown in Fig. 42 (*b*), with the pivot *g* that fits into the hub and about which the blade turns. The pin *h* of this blade fits into the slot *i* in the fork *j*, Fig. 42 (*a*) and (*c*). The fork is attached to the sleeve *d*, and as

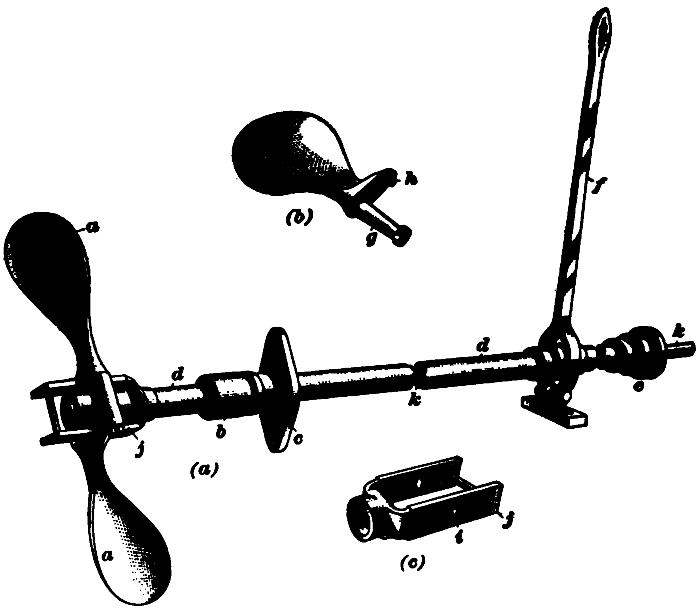


FIG. 42

the sleeve is moved forwards or backwards the fork moves the pins so as to cause both blades to turn about their pivots. The propeller shaft is shown at *k*. The sliding sleeve revolves with the shaft, but is free to be moved along the shaft by the lever *f*.

POWER-GAS PRODUCERS

CONSTRUCTION OF PRODUCERS

PRESSURE AND SUCTION TYPES

1. It is sometimes desirable or necessary to operate a gas engine independently of a central gas plant. In such cases, it is possible to produce the fuel gas required to run the gas engine at a lower cost than when using either illuminating gas or the more volatile grades of liquid fuel, such as gasoline and distillate of petroleum. This has led to the gradual development of an apparatus known as a **power-gas producer,** which is practically a small gas plant located near the engine, to which it furnishes gas. The process of making gas from coal, coke, or charcoal by means of such a producer is a simple one. The gas-generating and purifying devices are of such size as to be readily installed in power plants using gas engines and operating under ordinary conditions. They occupy but a small amount of space, and the attendance, even in a fairly large plant, requires only a portion of the time of one man.

2. Classification of Producers.—Modern gas producers may be divided into two general classes namely, *pressure producers* and *suction producers.*

In **pressure producers,** the gas is generated by forcing a blast of steam from a boiler, or of moistened air from a blower, through a bed of incandescent fuel. The gas is purified in a scrubber, stored in a gas holder of suitable capacity,

and supplied to the engine at a pressure of from 2 to 3 ounces. Pressure producers are generally used in large power plants and where more than one engine is supplied from the producer. They are also adapted to the use of different kinds of fuel.

In **suction producers**, air and water vapor at atmospheric pressure are drawn through the incandescent fuel by the inhaling or suction action of the engine, due to the partial vacuum produced in the engine cylinder during the suction stroke of the piston. The gas so generated is cooled and purified in the same manner as in the pressure producer. The volume of gas in a suction producer is thus never in excess of that required by the engine, and consequently it is not necessary to provide a holder, the gas being drawn directly from the producer to the engine cylinder. The amount of gas generated depends on the force of the suction or the number of inhalations transmitted from the engine cylinder to the producer. The engine governor controls either the volume of the charges or the number of charges required to operate the engine under any load.

3. Power Gas.—The pressure process of manufacturing producer gas for power purposes has not been materially changed since its introduction 20 years ago by Dowson, in England. Producer gas had previously been used for heating purposes, in which case it was desirable to keep the temperature of the gas as high as possible before being burned. In generating power gas the conditions and requirements are materially different, the desired object being the transformation of the heat in the coal into the chemical energy of cold gas, because it is only in a thoroughly cooled condition that gas can be used efficiently in engines.

In the pressure process of generating gas for heating purposes, the dry air is heated before being introduced into the producer; in the generation of power gas, on the other hand, the object is to reduce the temperature of the gas as much as possible by admitting to the producer a certain amount of air and water vapor, so that, when the mixture is brought in

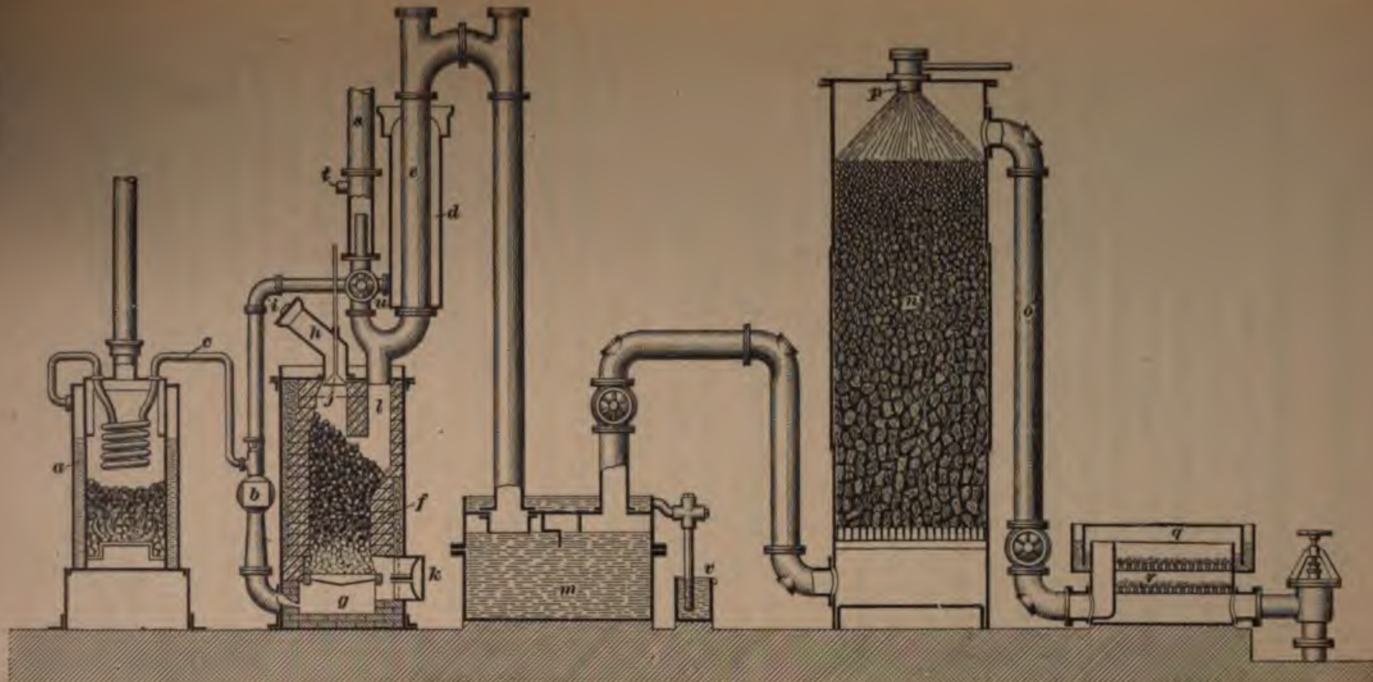


FIG. 1

contact with the burning fuel, hydrogen will be liberated. With even this cooling effect, however, the gases leave the producer at a temperature that is generally above 900° F.

The process of manufacturing power gas consists principally in heating some form of fuel to a very high temperature in a vessel from which the atmosphere can be excluded. The vessel in which the heating takes place is called **the producer,** or **generator.** The vessel in which water is heated, in order to supply moisture to the air that is admitted to the producer, is called the **evaporator,** or **boiler.**

After the gas is made in the producer, it is purified and used directly, or else stored in suitable tanks. The several steps in the process of gas generation will be treated in detail in connection with the various types of producers.

PRESSURE GAS PRODUCERS

4. One of the first types of pressure producers, as introduced by Dowson in England, and of which several plants have been installed in America, is illustrated in Fig. 1. The boiler *a* generates steam at from 60 to 75 pounds pressure, the steam being conveyed to the injector *b* through the pipe *c*. In the injector, the steam is discharged through a small nozzle, and the issuing current draws with it a certain amount of air from the casing *d* surrounding the pipe *e*, through which the hot gases leave the producer *f*. Thus the injector serves merely to deliver a mingled stream of air and steam to the ash-pit *g* of the producer, beneath the grate.

The producer consists of a cylindrical shell made of steel plates and lined with a highly refractory grade of firebrick. A hopper *h*, which is closed toward the atmosphere by a removable lid *i*, and against the interior of the producer by means of the bell *j*, conducts fuel to the producer while in operation. The bell being tight against its seat, the lid can be removed and the hopper filled with fuel. After closing the hopper, the bell is allowed to drop, permitting the fuel to enter the firepot of the producer, where it descends to the

e and is consumed, the ashes and clinkers being removed ugh the door *k*.

. The steam entering the producer is decomposed into gen and hydrogen while passing through the incandes- fuel. This oxygen, together with that which is in the mixed with the steam, unites with the carbon of the to form carbon dioxide and carbon monoxide. These s mix with those produced from the fuel by the : and pass upwards through the port *l* and the *e*. The pipe *e* is provided with fittings having remov- handhole covers, for the purpose of giving easy access ase it becomes necessary to clean the pipe. The gas is t forced through the water box *m*, where it is washed and t of the impurities removed; it then enters the scrub- *n*, which is filled with coke to within a few inches of the et pipe *o* near the top. As the gas rises in the scrubber, met by a descending shower of water distributed over entire area by means of the sprinkler *p*. The water cools gas and carries away some of the impurities, leaving a ll portion deposited on the coke. The coke is placed in scrubber with the larger pieces at the bottom, the sizes lually diminishing toward the top, and need not be wed for a period of from 1 to 2 years, according to quality of the fuel used in the producer and the unt of tarry matter contained in the fuel. After the becomes clogged, the scrubber is emptied and fresh provided.

ny dust or other impurities that the gas may contain r leaving the scrubber is removed while passing through purifier box *q*—sometimes called a sawdust purifier— ch consists of a square box with a removable top and con- s a series of wooden gratings *r*, over which are spread rs of sawdust or similar material. The gas is now ready e stored in a holder, not shown in the illustration, from h it is supplied to the engine in the same way as illumi- ng gas, but of course in larger quantity, proportionate to ower heating or calorific power.

6. The gas generated when the producer is first started is of very poor quality and unfit to be stored in the holder. It is therefore permitted to escape into the atmosphere through the smoke and waste-gas pipe *s*, until, by a test made at the tube *t*, the gas shows that it is of the proper quality, by burning with a bright blue flame. As soon as the quality has come up to the desired standard, the valve *u* in the waste pipe is closed, and the gas is allowed to pass on its way through the scrubber to the holder. The overflow from the water box *m* passes through the water seal *v*, which permits the water to flow to the sewer without allowing any gas to escape.

It will be seen, by an examination of Fig. 1, that all pipes between the producer and the holder are provided with fittings having handholes and covers, so that the pipes can easily be cleaned as occasion may require. It must be understood that, especially when using the poorer grades of coal, some of the impurities contained in the gas will adhere to the walls of the pipes, and in time sufficient quantities may accumulate to interfere with the free flow of the gas from the producer to the engine.

The pressure of the gas at the point where the injector *b* connects to the ash-pit of the producer is about 8 inches of water. This pressure gradually diminishes on account of the resistance that the gas encounters during its passage from the producer to the holder. Measured by a water gauge, the pressure in the pipe *e* between the producer and the water box is equal to about 6 inches; after leaving the scrubber, the pressure is 4 inches, and before entering the holder it is 2 inches.

SUCTION GAS PRODUCERS

7. Comparison of Suction and Pressure Producers. A comparison of the pressure producer with the suction producer discloses the fact that the chemical changes brought about in both types are practically the same. The difference between the two types is therefore not in the nature of the product,

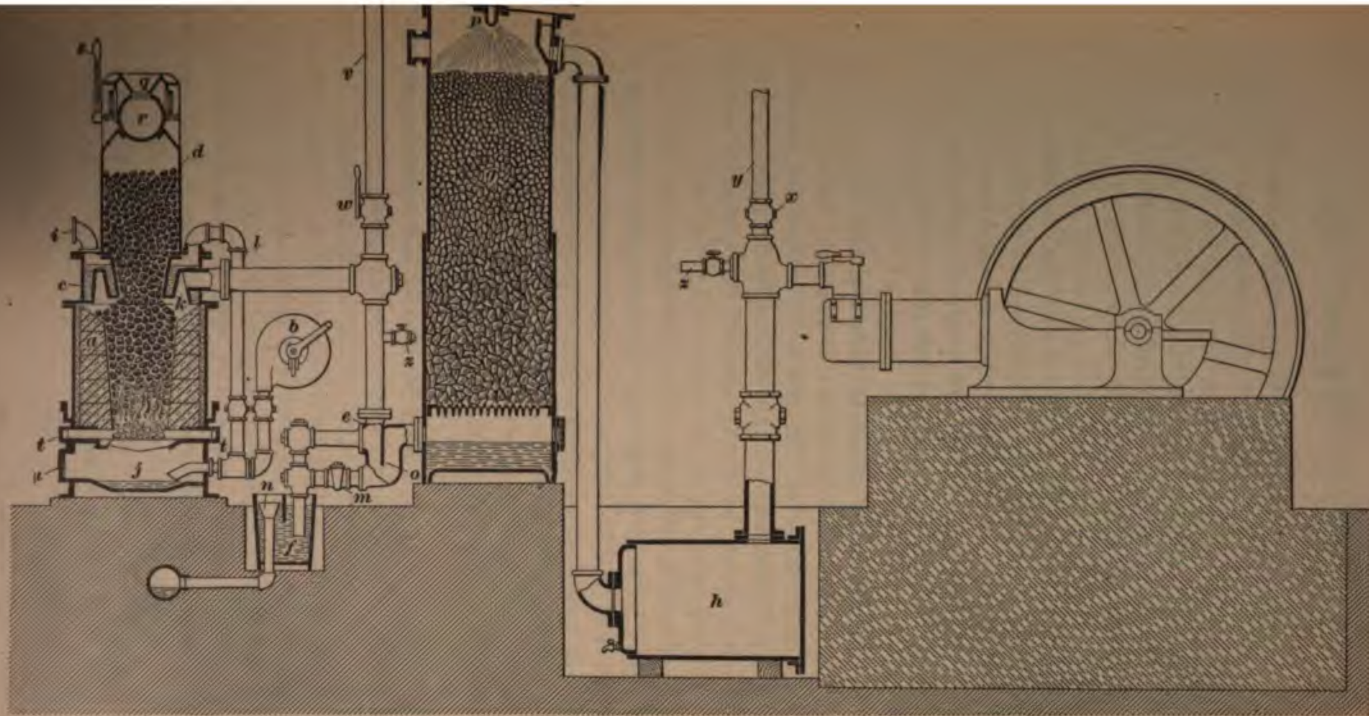


FIG. 2

but in the manner in which the gas is transmitted from the gas apparatus to the engine. The processes of generating and purifying the gas are the same in both cases; but in the pressure producer a pressure above that of the atmosphere is maintained by a forced draft, either from a low-pressure steam boiler or from a blower; while in the suction producer the pressure in any part of the apparatus or its connections is never higher than that of the atmosphere. The draft in the suction producer is furnished by the engine piston during the suction stroke while the inlet valves are open, and the vacuum created in the cylinder causes the gas from all parts of the producer apparatus to flow toward the engine.

The difference in pressure between the two systems is practically 8 inches of water; so that, in the suction producer, the pressure of the gas as it leaves the scrubber is about 6 inches of water below atmospheric pressure instead of 2 inches above, as in the case of the pressure producer. The relative difference in pressure in the various parts of the apparatus is the same in both systems, and the order of the operations of the process is necessarily alike in both cases. The suction type of producer does not require a large gas holder, a small cast-iron or sheet-metal tank being used instead. This tank is but slightly larger than the customary gas bag or pressure regulator used in connection with engines using illuminating gas.

8. Supply of Air and Moisture.—A suction gas producer of small capacity, in which the evaporator for supplying the necessary moisture to the air is mounted directly above the producer shell, is shown in Fig. 2. The apparatus consists of the producer *a* with a cast-iron shell; the hand-operated blower *b*, for reviving the fire after a shut-down over night; the evaporator *c*; the hopper *d*; the water trap *e*; the water-seal box *f*; the scrubber *g*; and the gas tank or reservoir *h*. At each suction stroke of the engine, air is drawn into the top of the evaporator *c*, through the elbow *i*, which is open to the atmosphere. The evaporator

is filled with water from a branch pipe taken from the main supply pipe and kept at a constant level by an overflow pipe, not shown in the illustration, that carries any surplus supply to the ash-pit *j*. The water in the evaporator is heated to about 170° F. by radiation from the burning fuel and by the hot gases that leave the producer through the port *k*.

The air passing over the surface of the hot water absorbs a quantity of vapor, the amount depending on the temperature of the water; so that the quantity of the water vapor admitted with the air through the pipe *l* to the space below the grate is greater when the fire is hot than when it is low. The fire is hottest, of course, when the engine is carrying a heavy load. Under heavy load, not only does the increase in the amount of vapor enrich the quality of the gas generated, but also the moistened air has a correspondingly greater cooling effect on the grate and tends to keep the fire at a proper degree of intensity.

9. After entering the ash-pit below the grate, the mixture of air and steam is drawn upwards through the hot bed of fuel, where the steam is decomposed into hydrogen and oxygen, and the formation of carbon monoxide takes place. After transferring a portion of its heat to the water in the evaporator, the gas leaves the producer through the port *k*, passes through the water trap *e*, and enters the scrubber at the bottom. The water trap has two pipe connections to the water-seal box *f*, the lower pipe being provided with a valve *m*. While the plant is in operation, this valve is open and the water that accumulates in the bottom of the scrubber flows through the lower connection to the seal box *f* and thence through an overflow funnel *n* to the sewer. When the plant is shut down, the valve *m* should be closed, thus causing the water in the trap *e* to rise well above the lower end of the partition wall *o*. This closes the gas connection between the producer and the engine. Any excess of water then flowing to the seal box passes through the upper pipe attached to the trap *e* and thence to the sewer.

10. Passage of Gas Through Scrubber.—While the gas is rising through the coarse coke in the scrubber *g*, it is met by a descending stream of cold water which is distributed evenly over the area of the scrubber by means of the sprinkler *p* attached to the top cover-plate. In this manner, the gas, from which some of its impurities have been removed while passing through the trap *e*, is now cooled and washed sufficiently to be delivered to the gas tank *h* in such condition that it contains no tarry or dusty substances to interfere with the successful running of the engine. When semianthracite or similar fuels containing higher percentages of tarry matter than pure anthracite or charcoal are used, it is necessary to add a sawdust purifier similar to that used in connection with the pressure producer shown in Fig. 1.

11. Supplying the Fuel.—The fuel is supplied to the producer shown in Fig. 2 through the charging device mounted above the hopper *d*, which consists of the funnel *q* and a smooth hollow ball *r* that can be turned on its ground seat by the hand lever *s*. The ball has an opening at the top, so that it may be filled with coal through the funnel, after which it is turned over by a quick movement of the hand lever, bringing the opening in the ball in communication with the coal space in the hopper *d*. As soon as the ball has thus been emptied of its contents, it is turned back and the operations of filling and emptying are repeated until the hopper is filled to the desired height. When not in use for filling the producer, the ball is held tightly on its seat with screws and hand nuts. The quick turning of the ball leaves but a small fraction of a second during which the hopper is open to the atmosphere, and practically no air is admitted to the producer at that point.

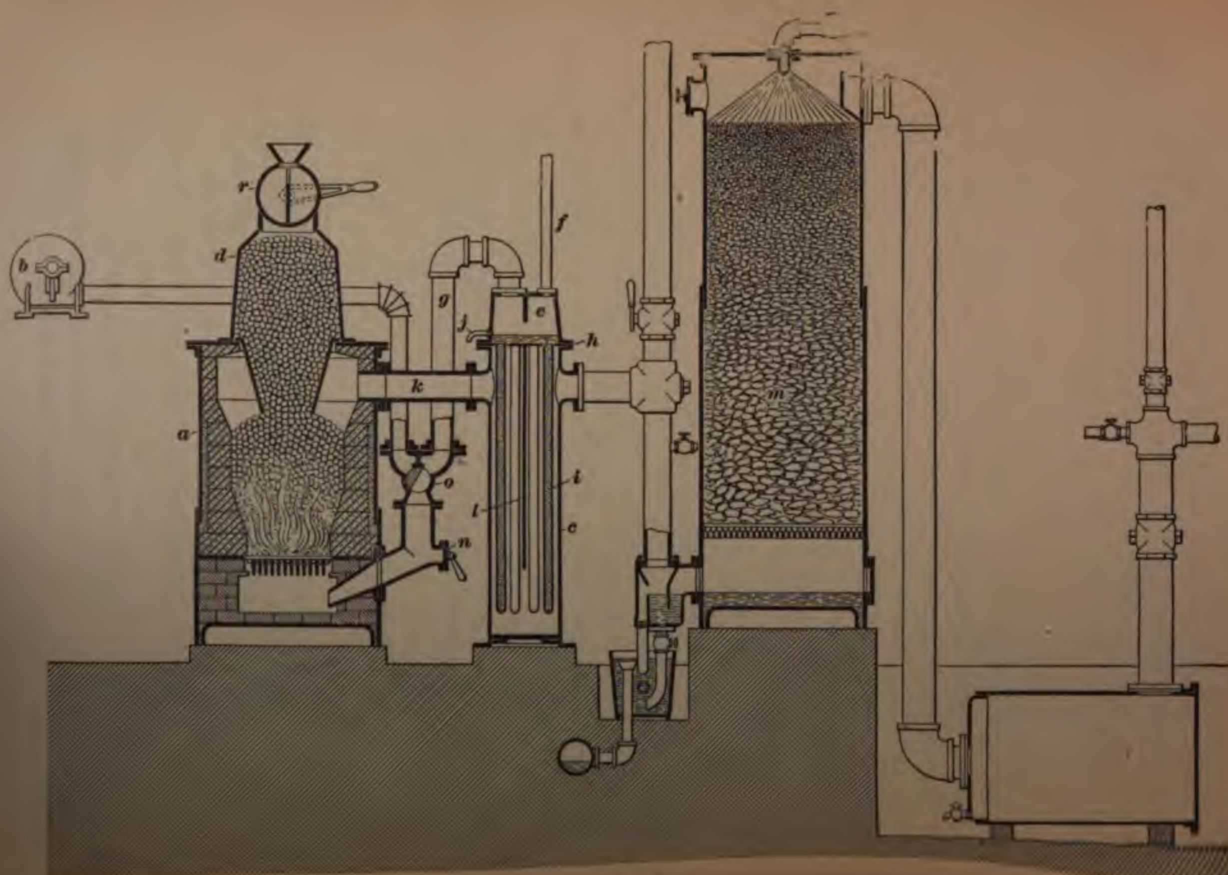
12. Removing Ashes and Clinkers.—The removal of clinkers that form in the fire space of the producer is facilitated by poke holes, with which the hopper is provided, that permit the fire to be stirred from above with suitable poking

rods. The clinkers descend to the grate and are removed through the two fire-doors *t*, *t*, on opposite sides of the cast-iron shell of the producer, while the ashes accumulating in the pit below the grate are drawn out through the ash-door *u*.

13. Starting the Producer.—The hand-operated blower *b* serves to supply the blast necessary to start up the fire after the plant has been shut down for any length of time, say over night. During such a temporary shut-down, the process of gas making is practically stopped, except for the small amount of gas generated by the natural draft caused by the flue pipe *v* being kept open to the atmosphere by opening the flue valve *w*. While reviving the fire, the valve *w*, as well as the valve *x* in the vent pipe *y*, is kept open until the gas escaping at the test tubes *z*, *z*—one of which is placed in the pipes between the producer and the scrubber, and the other near the inlet to the engine—is of such quality as to burn with a bright blue flame. As soon as this is the case, the valve *w*, and the valves in *z* and *z* are closed and the engine is started in the usual manner. To secure prompt starting, it is found advisable to keep the valve in the vent pipe *y* open to the atmosphere until a few explosions have taken place in the engine cylinder, and then close it.

LARGE-CAPACITY PRODUCER

14. A suction producer of larger capacity than the one shown in Fig. 2 and equipped with a separate evaporator is shown in Fig. 3. Instead of the cast-iron body shown in Fig. 2 in connection with the smaller type, the producer *a* consists of a shell built of steel plate and lined with fire-brick; but the hopper *d* and the coal-feeding device *r* are made of cast iron, and are essentially of the same construction as in the smaller producer. Instead of a hand blower, a belt-driven pressure blower *b* furnishes the draft for starting.


r
f
d
b
g
e
j
h
k
m
a
o
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l
n
c

The essential difference between the larger and the smaller plant is that the evaporator for heating the water in the smaller plant forms a part of the generator, while in the large plant it is a separate piece of apparatus and is connected to the generator by pipes. In the case of the larger, the evaporator consists of a cylindrical casting *c* with a hood *e* having a vertical dividing wall in the center, so that the air entering through the pipe *f* will be forced over the surface of the hot water in the evaporator before it passes to the ash-pit of the producer through the pipe *g*. Between the evaporator cylinder *c* and the hood is clamped a plate *h* carrying a number of vertical tubes *i* that are kept full of water, the level of the water being kept constant by an overflow pipe *j* slightly above the upper surface of the plate *h*. The hot gases leave the producer through the pipe *k*, and pass downwards and then upwards in the evaporator, being guided by the vertical partition *l*, and finally pass on to the scrubber *m*. In this manner, the water in the tubes is kept at the desired temperature, so that the required amount of vapor is taken up by the air while passing through the hood *e* to the ash-pit of the producer.

In order to be able to control the amount of moist and dry air used, a regulating plate *n* is provided in the air pipe, by means of which the air-supply pipe can be opened to any desired extent to the atmosphere in the producer room, thus admitting cool air that has not come in contact with the hot water. The three-way valve *o* serves to shut off the air connection to the evaporator when the fire is being revived by the blast from the blower. As soon as the gas has become of good quality, the blower is stopped and the three-way valve set so as to admit air in the regular way through the pipe *g*.

COMBINED PRODUCER AND EVAPORATOR

15. Another suction gas producer of somewhat different design is shown in Fig. 4. The producer itself consists of a cylindrical steel shell lined with firebrick and fitted with a

shaking grate *a* operated by the hand lever *b*. The hopper *c*, through which fuel is supplied to the producer, is sealed by the charging device *d*, so that any fuel placed in it can be admitted to the hopper without permitting air to

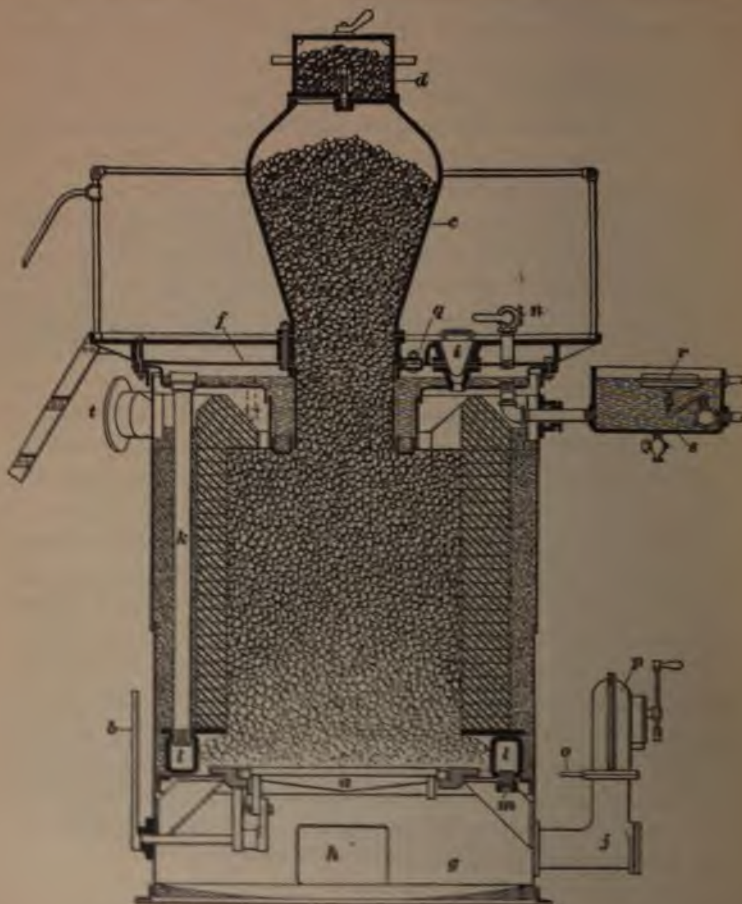


FIG. 4

enter the producer. From the hopper, the fuel descends into the fire-space through the feeding tube *e* surrounded by the evaporator *f*, in which the necessary steam is generated

at atmospheric pressure by the heat of the fire and of the gases when leaving the producer.

16. The ashes are removed from the ash-pit *g* through the door *h*. A series of poke holes *i* distributed over the top of the producer permits rods to be inserted for the pur-

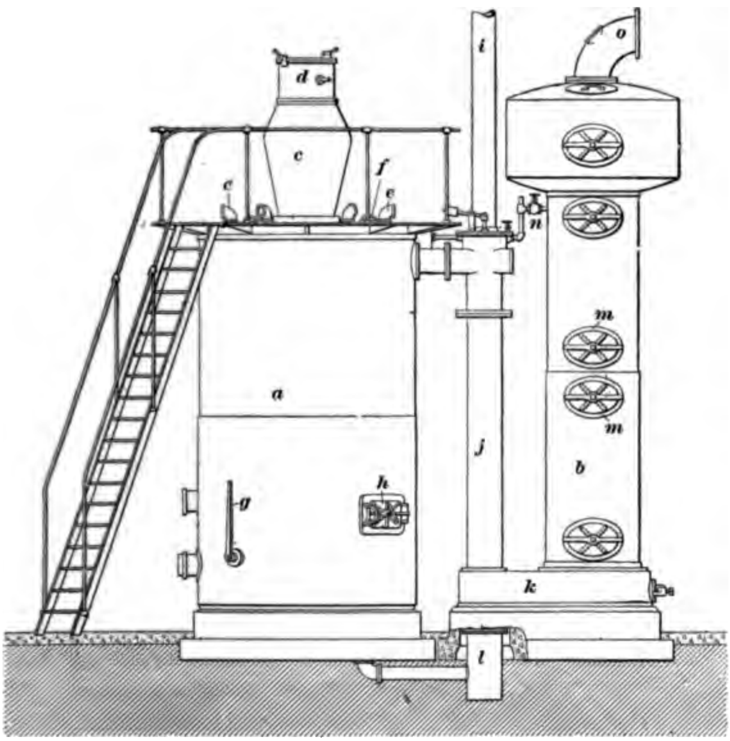


FIG. 5

pose of poking the fire and removing clinkers from the walls of the lining. Dry air is admitted to the ash-pit through the supply pipe *j*, while moist air, which is saturated with steam from the evaporator, is supplied to the ash-pit through pipes *k*, air boxes *l*, and nipples *m*. The air enters the top of the evaporator through the valve *n*. The proportionate

amounts of dry and moist air can be regulated as desired by opening or closing the valves *n* and *o*. The hand-operated blower *p* is used for starting or reviving the fire. Handholes *q* in the top of the evaporator are provided for the purpose of removing any sediment that may accumulate in the bottom of the evaporator. The water supply to the evaporator is automatically regulated by the float *r* that controls a valve in the water box *s*. The water rising in the box raises the float and closes the valve, while the lowering of the float opens the water valve. The gas passes from the producer to the scrubber through the pipe *t*, which is connected to the top of the producer.

17. An outside view of a producer of this type, connected to its scrubber, is shown in Fig. 5. The producer is shown at *a* and the scrubber at *b*. The hopper *c* with the filling device *d* is located over the producer and is readily accessible by the stairs and the platform around the top of the producer. The fittings *e*, *e*, admit the air to the evaporator, and the handles *f* are connected to the covers of the openings through which the fire is poked. The handle *g* is provided for the purpose of rocking the grate, and the door *h* gives access to the fire. The vent pipe is shown at *i* and the main gas pipe at *j*, connected to the scrubber at *k*, with the water trap *l* extending below the scrubber. There are a number of manholes *m*, *m*, on the side of the scrubber, to permit easy access to the interior. The water connections are shown at *n*, and the gas outlet from the scrubber at *o*. Producer plants of this style are made in units of from 15 to 250 horsepower, and are very compact and convenient.

DOWN-DRAFT PRODUCER

18. A gas-producer plant in which the draft is furnished by an exhaust fan operated by a small motor, drawing the gas from one scrubber and forcing it through another into a gas holder, is shown in Fig. 6. This apparatus consists of two similar generators *a* and *b*, an evaporator *c*, a wet scrubber *d*,

an exhaust fan *e*, a dry scrubber *f*, and the gas holder *g*. The gas generators are of the *down-draft type*, which is considered especially adapted to the use of fuels containing tarry matter, such as bituminous coal, wood, etc. The gas and tarry substances produced by the fresh fuel in the upper portion of the producer, pass down through the incandescent fuel bed, where they are heated to a very high temperature, and a gas free from tar is thus formed.

19. The generators consist of cylindrical steel shells lined with firebrick and provided with firebrick arches *h* that support the fuel beds. Openings *i*, *i'*, at the tops of the generators, serve for charging fuel, and for the admission of air, and the usual fire and ash doors are provided for cleaning the arches and for the removal of ashes. Steam jets *j*, *j'*, one in each generator, are supplied from the boiler *c*. The boiler is of the vertical type, and is connected by brick-lined flues *k*, *k'*, to the bottoms of the generators, the passages being controlled by water-cooled valves *m*, *m'*. The hot gases leave the generators at the bottom, pass through the evaporator, and impart a portion of their heat to the water contained in the space around the tubes. The steam produced is directed into the top of the fire by the jets *j*, *j'*. The hot gases pass up through the tubes to the outlet pipe.

20. The wet scrubber *d*, consisting of a cylindrical steel shell, contains a number of trays filled with coke moistened by the water sprays *n* and *o*. A purifier *p* filled with excelsior is attached to the top of the scrubber. The gas-inlet pipe *l* at the bottom of the scrubber is attached to a horizontal perforated diaphragm *q* submerged in water, so that the gas must pass through the water before rising in the scrubber.

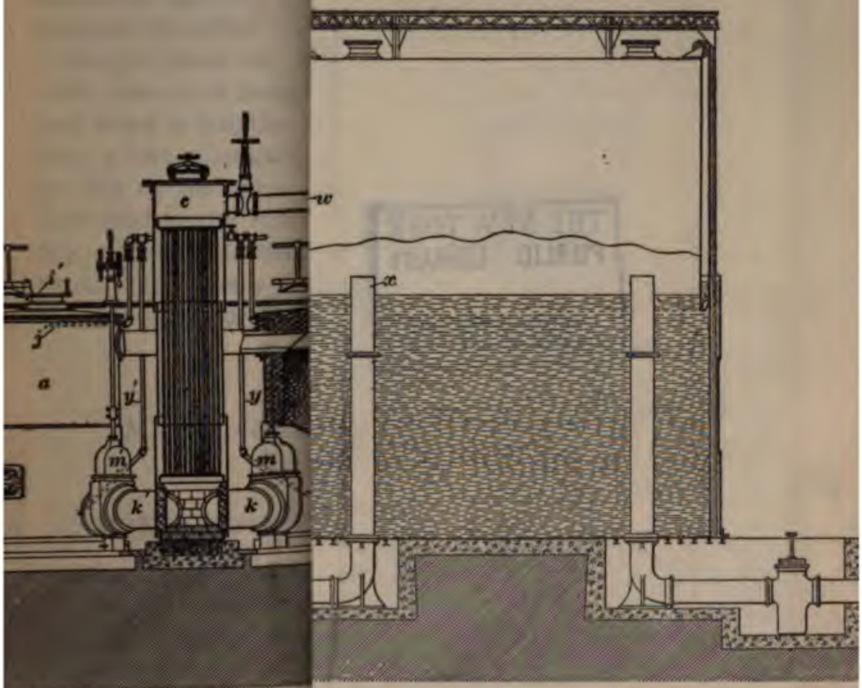
21. The fan or exhauster *e* maintains the necessary vacuum required to furnish the proper amount of draft and give sufficient pressure to deliver the gas to the holder. The motor that drives the exhauster is connected to the gas holder in such a way that the speed is automatically

regulated, by the movement of the holder, to conform to the demand for gas. When the holder is full, the speed of the exhauster is decreased; while in descending, as the gas is consumed, the motor speed is increased, creating a correspondingly stronger draft and a greater production of gas. The direction in which the gas flows after being delivered by the exhauster is controlled by the valves *r* and *s*. The valve *r* is connected to the waste-gas pipe and is kept open to the atmosphere while the fire is being started or revived. As soon as the gas becomes of the proper quality, the valve *r* is closed and the valve *s* opened, so that the gas can pass to the dry scrubber *f* and holder *g*.

22. The dry scrubber contains two trays *t*, *t'*, filled with excelsior, sawdust, or shavings. A horizontal partition *u* divides the scrubber into an upper and a lower chamber. The pipe connections to these chambers are fitted with valves, so that either the upper or the lower chamber can be connected to or shut off from the gas supply, thus making it easy to remove the trays, for the purpose of cleaning and recharging, without interrupting the operation of the apparatus. From the dry scrubber, the gas passes to the gas holder *g*, which consists of a stationary water tank *v*, filled with water, and an inverted movable tank *w*, which fits inside the water tank. The gas enters the holder through the pipe *x*, whose upper end is slightly above the level of the water in the tank *v*.

As the amount of gas in the holder increases, the movable tank *w* rises, giving additional space for the gas between the water surface and the top of the tank *w*. When the volume of gas in the holder decreases, the tank *w* descends. The pressure of the gas in the holder is thus kept constant. The lower edge of the tank *w* is always submerged, forming a water seal that effectually prevents the escape of gas.

23. While the apparatus is in operation, the generators *a* and *b* are open at the top, so that the attendant can observe the condition of the fire and add fresh fuel where needed.



§ 20

ıe condition of the fire may be regulated by occasionally ssing a jet of steam up through one and down through ǝ other generator, by means of auxiliary pipes *y*, *y'*, concted to the bottoms of the generators. The steam is roduced alternately in each generator; and the top door *i* d the valve *m* of one generator are closed and steam is wn into the ash-pit through the pipe *y*. This operation ıses an up draft through one generator and a down draft ough the other.

Should wood be used as fuel, the generators are filled th coke to a height of 3 or 4 feet above the arches *h*, d wood in lengths of 2 or 3 feet—or of ordinary cordwood e, 4 feet in length, if the generators are large—is placed top of the coke. The wood is ignited, and the gas is livered to the scrubbers and holders in the usual manner. steam is admitted at the top, however, as the wood ually contains a sufficient amount of moisture to render e gas of proper quality.

MANAGEMENT OF PRODUCERS

PREPARING PRODUCERS FOR OPERATION

24. Foundations for Producers.—The foundations for ducers should be built in accordance with plans furnished the makers. As a rule, it is necessary to set both the ducer and the scrubber on slightly elevated platforms of ck or concrete, to raise the apparatus to a level where it l be easily accessible to the operator and to bring the ious parts of the system in proper alinement, so that the es and fittings furnished by the maker will connect as ended. Special cases may occur where the conditions are h as to require some deviation from standard plans, and such instances the manufacturer of the apparatus should consulted and his recommendations and suggestions lowed.

Upon the arrival of the machinery at the place where it is to be installed, it is well to examine all the parts for defects and to clean thoroughly all vessels, castings, tanks, etc., of any packing material, dirt, or sand left accidentally in the castings at the foundry. This suggestion applies to the various parts of the gas producer, as well as to the pipes and fittings.

LINING THE PRODUCER

25. Firebrick.—Where the firebrick lining consists of special shapes, as is the case in most suction producers as well as in small sizes of pressure producers, the bricks should be carefully examined and any that are damaged, broken, or cracked, rejected. As a rule, a few extra bricks of each size are furnished, to allow for possible shortage of material that may be caused by the accidental breaking of some of the bricks while in transit.

Before attempting to place the lining in the producer shell, it is advisable to set the lining up on a floor or any other level place outside the shell, and to make sure that the various bricks fit without leaving excessively large spaces or crevices. If necessary, the bricks should be ground to each other, so as to remove any irregularities in shape and to reduce crevices to not more than $\frac{1}{8}$ inch at the joints. It is also necessary to see that the size of the lining is in accordance with the producer shell, that the circle formed by the bricks is not larger in diameter than the shell, and that, when making proper allowance for mortar, the total height of the lining will be such as to bring it up to the desired level inside of the producer.

26. Mortar.—After leveling the producer on its foundation, the laying of the firebrick lining may proceed. In preparing the mortar, care must be taken to use a grade of fireclay that will withstand the heat of the fire. As a rule, the manufacturer of the apparatus supplies the clay to correspond with the material used in making the bricks. The mortar is made of fireclay and water, and should be of about

the consistency of the cement mortar used in laying bricks for foundations. It is of great importance to work the mortar thoroughly, so as to make it smooth and of uniform composition. There should not be more than a layer of $\frac{1}{8}$ inch in thickness between the various courses of bricks.

Any openings or fissures that show on the inner surface of the lining, and that are therefore exposed to the heat of the fire, must be filled with a smooth pulp made of fireclay, asbestos, and water, of about the consistency of ordinary putty. This pulp will withstand the action of the hot fire, while mortar made of fireclay and water alone would crumble and fall away in a short time. The pulp must be rammed tightly into all fissures, and the whole inside of the lining smoothed up if the irregular shape of the bricks requires it.

It is of the utmost importance to have the inner surface of the lining as smooth as possible, so as to prevent clinkers from adhering to the wall. It also prevents the poking tools from catching in the joints of the brickwork and damaging the lining, when trying to remove the clinkers.

27. Filling Between Lining and Shell.—The lining is usually insulated from the shell of the producer by having the space between the bricks and the metal filled with a suitable material. Sand has been used, and if of the proper grade it will answer the purpose very well. The best sand for this purpose is molders' sand that has been used in the foundry for making iron castings. A much better material, however, although slightly more expensive, is *mineral wool*, which can be obtained at low cost almost anywhere. **Mineral wool** is made by subjecting molten slag to a strong air blast, the cooled product having a porous, fluffy appearance resembling cotton. Sand has the disadvantage of being liable to run out of any cracks that accidentally develop in the brick lining. This of course would necessitate taking enough of the producer apart to be able to replace the sand lost in this way. Mineral wool will stay in place as long as the lining lasts, and the freedom from danger of a shut-down, such as might occur where sand is used, will

more than pay for the additional first cost of the mineral wool.

28. Before filling the space between the lining and the shell, all the fissures around the fire-doors and the annular space around the bricks should be filled first, with a pulp made of fireclay, asbestos, and water, the same as that used for smoothing up the inner surface of the lining. Next the space should be filled with this pulp to a depth of several inches and then the mineral wool used up to within 2 or 3 inches of the top of the lining. The remainder of the space is then filled with pulp like that used in the bottom. This makes the whole space tight against leakage and keeps the insulating material in place, as the pulp will become hard after the fire is started in the producer. When putting in the mineral wool, it should be packed tight with a suitable tool as soon as a small quantity has been applied, and the ramming should be continued until the desired space is filled, so as to form a homogeneous mass of insulating material. After the lining and filling are completed, the top of the producer may be put in place.

FILLING THE SCRUBBER

29. After the scrubber has been placed in position, leveled up, and properly alined with the producer, the coke that is generally used as a purifying agent should be placed in the scrubber. In doing this, care should be taken not to break or grind the coke, and thus make dust and small pieces that will pack the coke tight and interfere with the flow of the gas through the scrubber. When the scrubber is to be entirely filled, the pieces of coke should be selected carefully as to size and the larger pieces placed in the bottom, the size gradually diminishing toward the top. The lower portion of the scrubber may contain pieces of about 4 inches in size, while nothing smaller than 1½ inches should be used at the top. To avoid breaking the coke in handling, it should be let down into the scrubber by means of a basket, a second

rope being fastened to the bottom of the basket, so that it can be tilted and emptied when it has reached the bottom. Another equally good method is for a man to stand on a board in the bottom of the scrubber and distribute the coke after it has been lowered into it. The contents of the scrubber should reach up to within about 6 inches of the lower edge of the gas-outlet pipe connected at the top.

Any coke that may accidentally fall through the scrubber grate should be removed from the space below the grate before the scrubber doors are finally closed. If this is not attended to, some of the small particles of coke may be washed into the pipe connections and cause trouble by clogging them.

PIPE CONNECTIONS

30. In making the pipe connections between the various parts of the apparatus, sharp bends should always be avoided, as they produce unnecessary friction and thus retard the flow of the gas in the pipes. Retarded flow is especially objectionable in connection with suction gas producers, and it is of considerable importance to provide long-sweep elbows rather than the ordinary cast-iron fittings. As producer gas always contains some impurities before it passes through the scrubber, it becomes necessary to clean the connecting pipes and fittings regularly. After leaving the scrubber, the gas may still contain a small amount of dust or tarry matter that will accumulate in the pipe connections. To enable the pipes to be cleaned without taking them apart, the fittings should be provided with handholes and removable covers, for the purpose of making their interiors accessible.

31. The flue valve in the waste pipe that branches off from the connection between the producer and scrubber is more liable to become clogged by impurities than any valve beyond the scrubber. This valve must therefore be arranged so that it can be easily taken apart to be cleaned and lubricated. It is desirable to provide a drip pipe and valve below

the flue valve, for draining any water that may collect in the smoke pipe either from the atmosphere or by condensation.

32. In order to have the smoke pipe constructed so as to give a good draft, which is essential in keeping the fire alive over night when the plant is shut down, it should be run in the shortest and most direct way possible. The general arrangement of the smoke pipe is of course governed by local conditions, but it should not have any sharp turns nor run horizontally for any length. If it is necessary to have a short length of horizontal pipe before the stack turns vertically, there should be a drain provided at the bottom of the elbow where the turn is made. The vertical length of the smoke pipe must be sufficient to insure a strong draft, and if there are any buildings in the vicinity the top of the pipe should be carried several feet above the top of such buildings. If this is not done, the gases that will escape from the stack while the fire is being started might cause annoyance to tenants of such buildings.

If the smoke pipe is led into an old chimney that has been used before, it should be carried up through the entire length until it reaches the open air. This is of special importance if any stoves are connected to the same chimney, because, if a fire was lighted in one of the stoves, gas issuing from the smoke pipe into the chimney might be ignited and result in a violent explosion.

TESTING FOR LEAKS

33. Whether the producer is of the pressure or of the suction type, it is equally important that the apparatus itself as well as all pipe connections be made absolutely tight. Neglect in this respect would cause leakage of gas in the pressure producer and result in danger to the health and life of persons in the producer room. While this danger does not exist in the suction producer, owing to the fact that the pressure in this type of apparatus is always below that of the atmosphere, small leaks would cause air to be drawn into the apparatus from the outside and result in weakening the

gas and in rendering it of such quality as to prevent good results from its use in the engine. If the leak is very serious, the gas would become so poor as to cut down the power considerably and eventually stop the engine.

34. Before attempting to make gas, all the joints and connections should be tested. A safe method of doing this is to generate pressure in the apparatus by closing the valves and operating the blower provided for reviving the fire. By attaching a small pressure gauge at a convenient point before the pressure is raised, and letting the apparatus stand for a while afterwards it can be determined whether there are any leaks. If the gauge shows a fall in pressure, it is necessary to investigate and locate the place at which the leak occurs. Each part of the apparatus can be shut off from the others, by means of the valves provided, and the point of leakage can thus be accurately determined. When the leak is located, it should be stopped.

The parts most likely to become leaky are the coal-charging device and the fire and ash-doors. In handling the fuel and the ashes, it is almost impossible to prevent impurities from settling upon the surfaces of the doors and charging apparatus. It is therefore advisable to always clean these surfaces after fuel has been admitted or ashes or clinkers have been removed.

OPERATION OF SUCTION PRODUCERS

STARTING THE PRODUCER

35. After it has been ascertained that everything about the apparatus is in good working order in accordance with the directions, the producer is ready to be put in operation. To start the fire, the generator should be filled, to a height of about 18 inches above the grate, with dry, non-resinous wood, or with charcoal. A small quantity of cotton waste soaked in oil and placed upon the grate under the wood will aid in starting the fire. If fat pine—sometimes called *pitch*

pine, on account of the amount of pitch it contains—or a similar wood is used to ignite the coal, a smaller quantity will be sufficient. In case the wood contains much pitch, no gas should be permitted to pass into the scrubber until the wood has been entirely consumed.

36. Before lighting the fire, the evaporator should be filled, and a small amount of water allowed to overflow into the ash-pit. The water-seal box should also be filled, and the water supply turned on in the scrubber as soon as the fire is started. The valve in the smoke pipe must be opened and the top of the hopper closed before lighting the fire. After igniting the wood, the ash-doors, fire-doors, and the pipe supplying moist air from the evaporator to the bottom of the producer must be closed. The connection between the blower and the producer is then opened, and the blower started, turning it either by hand or by power, as the case may be, until the wood is burning freely. Follow this by filling in about 8 to 12 inches of coal and continue blowing for a while until the fire is burning brightly. After this, the producer and hopper should be practically filled to the top with coal. Continue the operation of the blower until the gas at the test pipe between the producer and the scrubber burns steadily with a bright blue flame. Then close the communication between the blower and the producer, and quickly remove any ashes or clinkers that may have been deposited upon the grate. While doing so, the fire-doors through which these ashes are removed should be kept open no longer than is absolutely necessary.

37. Now reestablish communication between the blower and the producer and again operate the blower for a short time until the gas, by burning steadily with a blue flame, proves that it is of the proper quality. As soon as this is the case, all the apparatus, including the pipe connections between the scrubber and the engine, should be filled with gas, thus replacing the air with which they were previously filled. This is accomplished by closing the flue valve an-

also the vent pipe that branches off from the gas-supply pipe near the engine. The vent pipe is provided for the purpose of making sure that the whole pipe system up to the engine is filled with gas of good quality.

It will generally require from 10 to 15 minutes from the time of starting the fire until all the apparatus is filled with gas. There should also be a test pipe provided in the gas-supply pipe near the throttle valve on the engine. As soon as a trial at this point shows the gas to be of good quality, the plant is ready for operation and the engine can be started in the usual way.

FIRING THE PRODUCER

38. In order to secure steady and efficient service of the plant, it is necessary for the operator to accustom himself to performing the series of operations carefully and always in the same regular rotation. Experience has shown that the following method of procedure gives the best results: If the fire requires looking after, the first thing to do is to fill in fresh fuel practically up to the top of the hopper, so as to replace any coal that has been consumed during the run. The second operation should be the poking from the top. This is done for the purpose of removing any clinkers that may have begun to adhere to the walls of the brick lining, and also for the purpose of preventing the formation of hollow spaces in the hot bed of fuel known as *bridging*.

39. The fire should be poked at regular intervals, as determined by the quality of the fuel used and the experience the operator may gain while running the producer under the conditions of load in each particular case. It will not do to neglect removing the clinkers, because, if they should be allowed to accumulate on the walls of the brick lining in any considerable quantity, it would be impossible to remove them while the apparatus is in operation, and consequently it would be necessary to shut down the plant temporarily and interrupt the service.

40. The third operation should be the removal of the ashes from the ash-pit under the grate. This is generally done with a bent scraper. The fourth and last operation consists of poking and removing clinkers from the grate through the fire-doors. With a stationary grate, a bent poker is used for this purpose, after the clinkers have been loosened with a straight bar of suitable shape and length. This removal of clinkers through the fire-door should be done quickly; in order to prevent an excessive amount of air from entering the producer, open one door at a time just enough to permit of the removal of clinkers. If the producer is provided with two doors on opposite sides, close one door while the other is kept open. The whole operation of removing clinkers from the grate should not require more than 20 to 30 seconds.

These operations apply, of course, only to stationary grates. In producers provided with shaking or rotating grates, the cleaning is done by rocking or turning them by means of the hand levers or cranks provided for this purpose.

STOPPING THE PRODUCER PLANT

41. The engine is stopped as usual by simply closing the gas valve and disconnecting the battery. At the same time, in order to stop the producer plant in the proper manner, the valve in the vent pipe must be opened at once, so as to provide an escape for the gases that continue to form in the producer for a short time after the engine has been stopped. Next, the hopper of the producer should be filled with fuel and the flue valve in the smoke pipe opened. As soon as this valve is opened, the valve in the vent pipe near the engine can be closed. The water supply to the scrubber and producer should then be shut off and the valves adjusted that regulate the level of the water in the seal and water trap between the scrubber and producer, so that the gas will be shut off from the scrubber. Experience will show just how far to open the air supply that regulates the draft necessary to keep the fire alive over night

without unnecessary waste of fuel while the plant is shut down.

The ashes and clinkers should be removed from the producer, and the fire and ash-doors kept closed. Should it become necessary to remove large quantities of clinkers, it will be found easier to do this immediately after stopping the plant and while the fuel is still incandescent. It is best, in such cases, to draw the fire completely and to remove the clinkers from above after opening the cover of the hopper.

RESTARTING THE PRODUCER

42. To start the plant after it has been shut down over night, it is necessary only to remove from the grate any ashes or clinkers that may be deposited during the night, and to operate the blower until the gas burns with a bright blue flame at the test tube between the scrubber and the engine. Then open the vent and the scrubber valves, see that the hopper is closed tightly, and start the engine in the usual way.

CLEANING THE PIPE CONNECTIONS

43. It is always advisable to attend to the cleaning of pipes and fittings in the day time, so that it will not be necessary to use a light, as a flame brought too close to the apparatus might ignite the gas. It is also advisable, as a matter of precaution, to have more than one person present while the cleaning is being done, so as to guard against accidents.

The building or room in which the producer is located should be well provided with ventilators, so that any escaping gas will be quickly carried away. The gas is very poisonous, and, if it accumulates, is liable to render the workmen unconscious and may cause death. Hence special care should be taken to avoid breathing it. Under ordinary conditions it will be found sufficient to have the pipes examined and cleaned once in 3 months.

44. The contents of the scrubber may last for a year or more before they require renewing. If it becomes necessary to clean the scrubber, the whole producer must, of course, be put out of commission. The manholes of the scrubber should first be opened, so that any gas contained in the scrubber may escape. It may require about 1 hour or more for the gas to stop, after which the coke may be removed. Any sediment that may accumulate in the bottom of the water-seal box, at the bottom of the scrubber, should be cleaned out at least once every other day.

OPERATION OF PRESSURE PRODUCERS

45. The directions already given for the care of producers apply especially to suction producers, but they are almost equally applicable to pressure producers, especially in regard to the firebrick lining, pipe connections, etc. But the arrangement of the fuel bed is different in the pressure type from that used in the suction producer. Instead of having on top of the incandescent fuel a large amount of coal that is not burning, the height of the fuel bed is limited to from $2\frac{1}{2}$ to 3 feet above the ashes when using anthracite, and from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet when using bituminous coal. This will require a pressure for the air blast of from 3 to 4 inches of water.

If the blast is too strong or the coal too fine, the fuel will burn too fast near the walls, and it will be necessary either to reduce the blast or to use a coarser grade of coal. To keep the fuel bed reasonably solid and avoid the formation of bridges or honeycombing, a certain amount of poking, or barring, must be done, the frequency of which depends on the character of the fuel or the rate at which the producer is working. A little experience and careful observation will enable the operator to determine just how often the fire needs attention, so as to keep it in the best condition for steady service.

When stopping a pressure producer, no unburnt coal should be left on top of the fuel bed; the top layer should be incandescent. The blast should be decreased just before

stopping, the poke-hole caps removed, and the escaping gas lighted at the open holes. Then the blast may be shut off entirely. Air will be drawn into the producer by the receding flame, so that the gas in the producer will burn quietly without any violent puff.

BLAST-FURNACE GAS FOR GAS ENGINES

QUALITY OF GAS FROM BLAST FURNACES

46. The use of blast-furnace gas for gas engines is of recent origin, and cannot yet be said to have passed much beyond the experimental stage. The blast furnace is used for melting iron ores and producing pig iron. The furnace varies from 40 to 100 feet in height, and from 12 to 25 feet in diameter. The fuel employed is coke, and the air blast used to promote combustion produces a temperature sufficiently high to melt the ore, and has a pressure of from 5 to 15 pounds per square inch above that of the atmosphere. The amount of gas that passes from the blast furnace is about 150,000 cubic feet per ton of pig iron produced. In order that the iron may not combine with oxygen passing through the furnace, the amount of air admitted is insufficient to complete the combustion of the fuel, and hence the gas passing out of the furnace contains a large amount of carbon monoxide. Blast-furnace gas, however, is not as rich in combustible matter as is producer gas, but it contains enough combustible matter to furnish considerable power when used in gas engines of suitable design. The average composition of blast-furnace gas is about as follows:

Gas	Per Cent.
Carbon dioxide, CO_2	.08
Carbon monoxide, CO	.30
Hydrogen, H	.02
Nitrogen, N	.60
Total	100

There is usually present some hydrocarbon that affects these percentages to a slight extent. The thermal value of blast-furnace gas varies from about 90 to 100 British thermal units per cubic foot, depending on the percentage of carbon monoxide present. The fact that the gas is low in hydrogen and rather high in carbon monoxide makes it desirable for gas engines especially designed for its use. It has been found, in practice, that the gas from the blast furnace will furnish about 50 horsepower continuously for each ton of pig iron produced in 24 hours.

47. One of the principal difficulties to be contended with in connection with the use of blast-furnace gas in gas engines is the large amount of gritty dust that the gas contains. This necessitates very careful and thorough cleaning of the gas before it is admitted to the engine cylinder. The gas should be as nearly free from solid matter as it is possible to make it by any cleaning method now in use. When the gas comes from the blast furnace, it usually contains from 4 to 7 grains, and may contain as much as 12 grains of dust per cubic foot; its temperature is also high, ranging from about 500° to 1,000° F. or more. The amount of dust contained has been reduced by some of the best modern cleaning processes to as low as .01 grain per cubic foot, and even less, which is said to be less than the dust contained in ordinary air.

When the gas from the blast furnace is not sufficiently cleaned before it goes into the gas engine, the dust collects on the inner surface of the cylinder, and, as the piston moves to and fro, the dust is ground between the piston and cylinder, thus causing excessive heating and perhaps cutting of the surfaces. Sometimes, the dust collects in the combustion chamber or valves, becomes incandescent from the heat of the explosions, and causes preignition.

48. To get the greatest efficiency from the combustion of the gas, it should be cool and dry as well as clean. The high temperature of the gas causes it to evaporate some of the water used in the cleaning process and to carry with it a

large percentage of moisture. This moisture is detrimental to the combustion, but is a great aid in getting rid of the dust. The particles of dust are moistened by it, and adhere more readily to any surface with which they come in contact. But the moisture must be removed before the gas enters the engine. This is done by cooling the gas, thus causing the moisture to condense. As it condenses, it falls by gravity to the bottom of the apparatus, carrying with it a considerable amount of dust.

The gas is forced through the cleaning apparatus by a steam jet or by some form of fan or blower.

CLEANING BLAST-FURNACE GAS

49. In the earliest blast-furnace gas-engine plants, the gas was cleaned by about the same process used in a producer plant. It was found, however, that this process did not clean blast-furnace gas sufficiently for use in gas engines. Hence the cleaning process was extended by adding scrubbers and rotary washers to the apparatus already in use. In some cases, the rotary washer was simply a fan with provision for spraying water into the gas; while in others, it took the form of an enclosed rotating drum or series of disks partly submerged in water. The gas being forced through the washer came in contact with the large wetted surface to which the particles of dust adhered, and as the surface revolved into the water the dust was washed away. A still later development is represented by the centrifugal cleaner, in which the gas is carried around inside of a casing by a revolving drum with projecting vanes, the speed being such that the centrifugal force throws the dust against the casing, from which it is washed by a spray of water.

50. Cleaning Plant With Rotary Washer.—The gas is carried in flues or pipes from the blast furnace to the cleaning apparatus and engines. It is taken from the flue leading downwards from the top of the furnace—known as the *down-comer*—and conducted to a main, which may

also receive the gas from other furnaces. It then passes through a washing process that takes out the larger particles of dust and grit. Next, the gas goes through a long pipe or series of pipes that reduce its temperature and take out considerable dust and moisture. In the first washing process, the gas takes up considerable moisture, and the dust, becoming moist, adheres readily to the surfaces with which it comes in contact. From the long pipes, the gas may pass through a rotary washer consisting of a fan or a drum with vanes on its circumference with a spray of water injected into it. The whirling motion given the gas as it passes through the fan throws the dust against the casing, to which it adheres and from which it is washed into a water outlet by the injection water. From the fan or rotary washer, the gas may pass through other scrubbers or washers similar to the coke scrubber or sawdust cleaner described in connection with the producer-gas plant. Sometimes, two scrubbers or cleaners are used, in which case the gas passes first through a coke scrubber and then through a sawdust cleaner for removing the finer particles of dust. From the last cleaning process, the gas is taken in many plants to a gas holder of considerable size, where the remaining moisture in the form of vapor is condensed by cooling and settles with the remaining dust

From the gas holder, the gas is conducted directly to the engine cylinder. The gas holder serves the double purpose of a cleaner and a regulator or equalizer of the pressure of the gas delivered to the engine. The pressure of the gas in the holder will usually vary from 1 to 2 or more ounces per square inch above atmospheric pressure.

When the rotary washers are properly designed and installed, the scrubbers between the cleaner and gas holder and the long pipes may be dispensed with, thus reducing the size, first cost, and operating expenses of the cleaner plant. Furthermore, the gas is cleaned much better than in the cleaners used on producer-gas plants.

51. Centrifugal Cleaning Plant.—In the cleaning plants that have given the best results with European

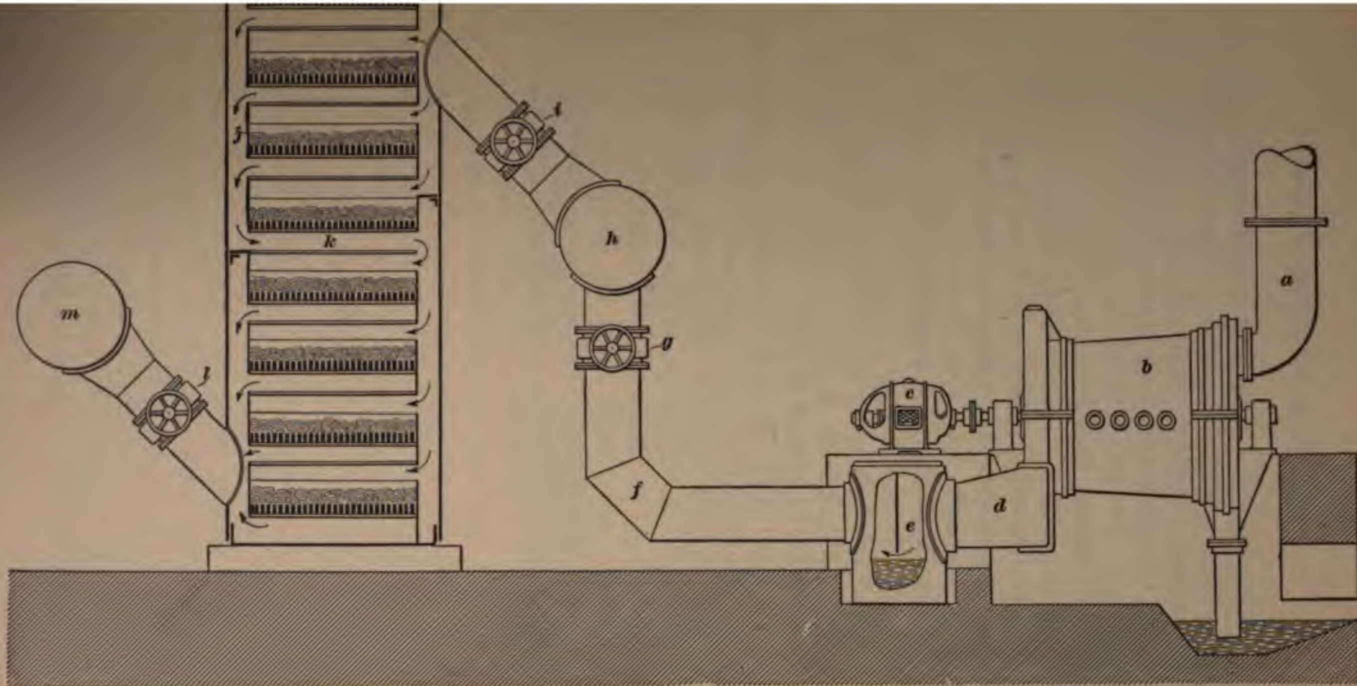


FIG. 7

blast-furnace gas, a rotary or a centrifugal washer forms the principal part. In some plants, large, slowly turning washers are used; while in others, small and rapidly turning centrifugal washers are employed. In the first, the cleaning is done by bringing the gas in contact with a long revolving surface that dips into the water at every revolution, thus washing off the collected dirt and wetting the surface. In the second, the gas is driven by centrifugal force against the sides of the casing and the dirt washed out with a spray of water.

A centrifugal plant for cleaning blast-furnace gas is shown in Fig. 7. Before the gas reaches the centrifugal cleaner, it is passed through a dry stationary dust catcher, or cleaner, where larger particles of dust are removed. The stationary cleaner may be simply a large closed drum in which the velocity is low and the dust is allowed to settle out by gravity; or it may be a smaller drum and contain deflectors for changing the direction of motion of the current of gas. From the dust catcher, the gas passes down through the pipe *a* to the centrifugal cleaner *b*. The internal drum of the centrifugal cleaner revolves at about 850 revolutions per minute, thus producing sufficient velocity in the gas to cause the particles of dust and dirt to fly outwards against the casing, under the influence of the centrifugal force. The gas usually carries from 1 to 3 grains of dust per cubic foot as it leaves the dry cleaner, and the centrifugal cleaner reduces this amount to about .01 grain per cubic foot before the gas leaves. The moisture in the gas, however, is increased, and for this reason the use of a dryer or dry filter is found advisable. The centrifugal cleaner *b* is driven by a motor *c*, the gas leaves by the outlet *d*, and passes around the baffle plate in *e*, where some of the moisture is precipitated. The gas then passes through the pipe *f* and valve *g* to the main *h*, from which it can be drawn off at different points, as desired. The valve *i* opens to the dry filter *j*, which contains trays carrying slats covered with mineral wool or other drying substance, through which the gas passes in the direction shown by the arrows. The dry filter is divided into two compartments by the partition *k*,

the gas passing through one tray of mineral wool in each compartment, leaving it comparatively dry. The valve *l* regulates the opening to the main *m*, which conducts the gas to a holder or directly to the gas engines.

52. The Centrifugal Cleaner.—A larger view of the centrifugal cleaner is shown in Fig. 8. The blast-furnace gas enters the cleaner through the opening shown at *a*. The casing *b* remains stationary, while the drum *c* is keyed to the shaft *d*, with which it revolves. The small vanes *e* are arranged in the form of a spiral around the drum *c*, so

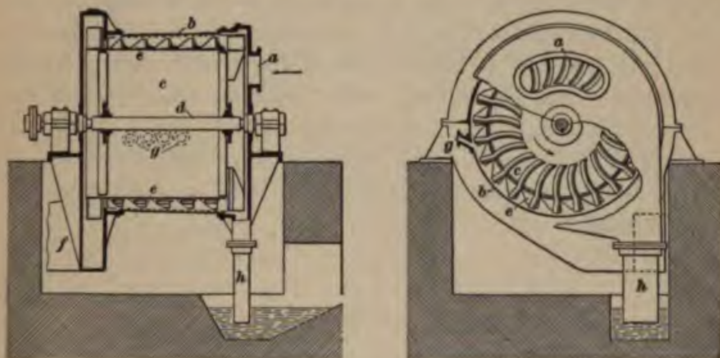


FIG. 8

that the gas must pass through a long passage or be thrown against the outer casing as the drum revolves. The gas leaves the washer through the outlet *f*, and passes to a dry filter, as previously described. Water is sprayed against the revolving drum through the inlets *g*, and is carried around by the vanes of the drum with sufficient speed to keep the casing wet and furnish water for washing off the dust as fast as it collects. The dirty water passes out through the water leg *h* to a drain.

The gas that enters the cleaner is still hot, sometimes having a temperature as high as 300° or even 400° F. It consequently vaporizes some of the water when it first comes in contact with the wet surfaces of the centrifugal

cleaner. This vapor mingles with the dust in the gas, and the centrifugal force throws the vapor and dust outwards, causing them to come in contact with the outer casing, to which they adhere. A wire screen is located inside the casing where the injection water enters, so that the water is at once broken up into fine particles, offering more surface to the dust and being more easily vaporized. The temperature of the gas is also reduced by the water, the amount varying from 60° to 260° F., depending on the temperature of the blast-furnace gas, the temperature of the water, and the efficiency of the cleaner. It is customary to keep the water stored in elevated tanks, and feed it to the washers by gravity and to discharge it into clearing ponds. The dust and dirt are allowed to settle out of the water, which is then pumped through cooling coils back to an elevated tank, from which it again flows to the cleaner by gravity. The water is thus cooled and cleaned, and hence can be used over and over again with the addition of a small amount of fresh water.

MANAGEMENT OF AUTOMOBILE ENGINES

CARE AND ADJUSTMENT

INSPECTION, AND LOCATION OF FAULTS

1. The owner or chauffeur who for the first time takes charge of an automobile must, especially if the machine is a new one or of an unfamiliar type, make a searching examination of the condition of the automobile before it will be prudent or even safe for him to attempt its operation. This examination should not be limited to the engine and its accessories, but should include all parts of the car. In the following articles, attention is directed to the parts of the engine that should receive careful attention.

2. In the first place, a general survey of the engine should be made—particularly if it is of an unfamiliar type—special attention being given to the location and mode of action of each individual part included in the valve mechanism, the ignition mechanism, and the governor, pump, radiator, carbureter, etc. Attention should be given to the steps necessary to be taken in order to expose, for examination, the working parts of the engine, such as, the two-to-one gears (if these are enclosed), the pump, the cams, the igniters (if these are of the contact variety), the magneto (if any), and the interior of the crank-case, so far as this can be reached

without dismantling the engine. On completing this preliminary investigation, the condition of the various parts should be examined in detail.

3. The float valve of the carbureter should be tested for leaks by opening the valve between it and the tank and looking for gasoline drip. If gasoline escapes, it may simply be because the float is set too high, so that it does not close the needle valve before gasoline issues from the spray nozzle. Or, it may be that the valve itself leaks.

At this stage, it is well to assume that the float is properly adjusted, and to begin by shutting off the main gasoline valve, and then unscrewing the washout plug below the needle valve. It may be found that dirt, waste, or a splinter of wood has got past the strainer, through which, presumably, the gasoline passes on its way to the float, and is lodged in the needle-valve opening. It may be of advantage to open the top of the float chamber, which can usually be done without disturbing other parts, and take out the float and needle valve. A little gasoline washed down through the needle-valve orifice will then generally carry away any dirt that may have clung to the valve when the plug was unscrewed. If the gasoline still drips when the parts are reassembled, the mixing chamber should be opened and the top of the spray nozzle examined to see if gasoline is escaping from it. An electric light should be used in making an examination of the carbureter, as, with any other illuminant, a fire might be started. The portable electric flashlights sold everywhere at a moderate price answer the purpose very well.

4. If gasoline is escaping from the spray nozzle, the needle valve of the float may be carefully ground in, by placing between the valve and its seat a paste made of powdered grinding material and oil or water, using for this purpose either very fine sand, or, preferably, pumice or rottenstone. The method of regrinding valves will be explained more fully in *Troubles and Remedies*. Emery should not be used, as it will embed itself in the brass valve or seat-

A little of the sand or pumice should be mixed with oil to make a paste. The mixture is applied to the needle point, which is then rotated by quarter turns in its seat with slight pressure, taking care to keep the stem as nearly vertical as possible and frequently adding fresh paste.

If this does not stop the leaking, it is likely that the float is too high; but, unless the gasoline escapes very rapidly, it is better not to disturb the float until attention has been given to other more important details. The car, however, should not be left standing with the main gasoline valve open, for the dripping gasoline may catch fire from the lamps, from a stray spark in the ignition circuit or at the timer, or from a match accidentally dropped near the valve.

The manner of adjusting the carbureter should be noted, but the adjustment should not be disturbed unnecessarily, as it is often hard to get the right mixture after this has been done.

5. Next to making sure that there are no gasoline leaks, the most important thing is to see that no bearings are too tight or have seized, owing to lack of oil or the bending of the shaft or connecting-rods. The compression relief cocks should be opened and the shaft turned over slowly by hand. The shaft should move with entire freedom, a little more easily at the beginning and end of the piston stroke than at mid-stroke, because of the slower movement of the piston at the ends of the stroke, but with no binding or sticking at any point. If the shaft turns hard, the car should be taken to the repair shop, since probably either the bearings or the pistons are cut, or the shaft or rods are sprung out of true, as, for example, from having struck a loose nut or other obstruction in the crank-case, or from preignitions in the cylinders. Fortunately, serious trouble of this sort does not often occur.

At the outset, it is well to locate all loose bearings, since these require more lubrication than properly fitted bearings. If they are very loose, there is a strong likelihood that they have been cut, in which case they ought to be opened,

scraped, and refitted at the earliest possible moment. Of the main-shaft bearings, that next to the flywheel is the most likely to be loose. If the engine is vertical, a jack may be put under the flywheel and the jack-lever worked gently up and down to disclose looseness, if any, in this bearing.

6. To expose the crankpin bearings of a vertical motor, it is sometimes necessary to take down the bottom half of the crank-case, which is generally attached to the upper half by capscrews or studs, and which simply serves the purpose of an oil pan. Under this arrangement, the shaft bearings are usually supported from the upper half of the crank-case, which is itself supported on the frame of the car. Nevertheless, it is advisable, when slackening the screws or the nuts on the studs, to find out whether or not they are carrying the weight of the crank-shaft. This can be done by slackening all the screws several turns, and then pushing upwards against the oil pan with the hand to see how much pressure is necessary to lift the pan off the screws. If the shaft is found to be resting on them, it will be better not to take it down at once, unless it is evident that the main-shaft bearings themselves need attention. Generally, if the shaft is supported by the bottom half of the case, the crankpin bearings can be reached from handholes located in the bottom or sides of the crank-case.

The crankpin bearings can be tested for tightness by setting the engine at mid-stroke and oscillating the flywheel very gently back and forth while the fingers of one hand are resting on the edge of the crankpin bearing. A slight looseness may be allowed, provided the lubrication is sufficient, and there is no cause to suspect that the bearings have been cut. The amount of permissible looseness will depend to a great extent on the particular engine and the speed at which it is to run. A vertical four-cylinder engine running at moderate speed will bear as much as .002 inch of lost motion on the crankpins, but if the same engine is run at a high speed this will be too much.

7. The main-shaft bearings will bear less lost motion than the crankpins, and if one bearing is worn more than another, as is likely to be the case, it will result in one-sided wear of the crankpin bearings, due to the settling of the shaft. The main-shaft bearings ought not to have more than .001 inch of play before being taken up, but more than this is often found.

A double-opposed horizontal engine will, sooner than any other type, develop a pounding sound, generally called a *pound*, at the main-shaft bearings, owing to the fact that the explosions occur alternately in opposite cylinders, and there is nothing to keep the shaft against one or the other side of its bearings.

8. In addition to the inspection for loose bearings, the principal nuts and screws should be tested to see that they are tight, and if any cotter pins are missing from bolts, studs, or slotted nuts, they should be supplied at once. The bolts on the crankpin bearings should also be examined for tightness, and to see that cotter pins are supplied.

9. If the inlet valves are automatic, see that they work freely in their guides, that they do not leak, and that their springs are not too weak. If there is more than one cylinder, the inlet-valve springs must be alike in tension. If the valves stick, they may be freed by squirting a spoonful of gasoline on them. If they leak, they should be ground in, as described later.

The openings of the valves should be determined to some extent by their diameters. Valves up to 2 inches in outside diameter generally lift about $\frac{1}{8}$ inch, and slightly more than this if they are larger. The keys through the valve stems should be examined to see that they are not on the point of breaking.

The tensions of the valve spring on similar valves of the same engine should be equal; their equality may be tested by pressing the ends of the valve stems together while the valves are held by their cages, as shown in Fig. 1. The valves should begin to open with about the same pressure,

and should also reach full opening with equal pressures. If one spring is weaker than the others, it may be taken off and stretched gently. Too great a lift makes the valve sluggish in closing, and permits a portion of the fresh charge to be forced backwards through the valve at the beginning of the compression stroke; this prevents the engine from attaining its maximum speed. When the valve opening is too great, it may be reduced by slipping a washer over the stem. For this purpose, some sort of a spring washer is preferable, but not essential A makeshift of soft wire will not do, as the hammering of the valve will soon break it, and a bit of wire may make a great deal of trouble by getting into the cylinders.

FIG 1

10. The user should satisfy himself regarding the lubrication of every part of the engine. Every oil pipe should be traced, and every oil cup and oil hole located and the purpose of each ascertained. Oil pipes leading from the automatic lubricator should be disconnected close to the bearings or cylinders, and the lubricator worked by hand to see that it is feeding properly. Generally, this can be done by working the pump plungers up and down to the extent of the lost motion on the pump eccentric. If this cannot be done, the delivery of oil may be watched after the engine has been started.

If an oil pipe is clogged it should be disconnected close to the lubricator; and if no oil comes from the lubricator at that point the cause of stoppage should be located. The trouble will probably be found to be caused by dirt or waste under the check-valves of the pump. If oil comes from the lubricator

when the pipe is disconnected, the latter is stopped up, and can be cleaned by running a wire through it. Generally, however, any obstruction of this sort will travel to the end of the pipe and lodge in the check-valve, if there is one at that point, so that the check-valve should be unscrewed and examined.

11. The manner in which oil is supplied to the crank-pins should be ascertained, since these are sometimes fed simply by internal splash and sometimes by centrifugal ring oilers and oil passages drilled through the cranks. If internal splash is relied on, the user should see that the crank-case contains enough clean oil to allow the connecting-rod caps to dip into it about ½ inch at the lower end of their stroke.

If the car has not been used for a considerable time, the oil in the crank-case, oil cups, and reservoir is likely to be stiff and gummy. If this is the case, the oil should be drawn off, and a moderate quantity of kerosene used to make sure that the oiling system generally is thoroughly clean. Before starting the motor, a liberal supply of fresh oil should be provided, as the kerosene will cut away the old oil wherever it reaches, and the pistons, cylinders, and bearings might become cut before the fresh oil can reach them from the reservoir. When oil has not been cleaned out in this manner, it is a good precaution, on general principles, to put a pint or a quart of fresh oil into the crank-case. If, however, on starting the motor it is seen that a considerable quantity of white smoke is being produced, the crank-case has evidently too much oil, and a portion should be drawn off.

12. The ignition circuit should next be gone over. This should be done with the switch closed and the safety plug—that is, a plug the removal of which will break the circuit—if one is used, inserted in the switch or coil, the gasoline shut off, and the compression relief cocks (if any) open. The positions of the lever controlling the spark for early and late ignition should be ascertained by a careful examination of the timer, and the lever should be set for a late, or retarded,

spark, as a precaution in case of any accidental explosion in the cylinders. The engine should be turned over slowly, and the sound of each of the vibrators on the coils noted. The sound should be clear and regular, and fairly high without being tinny. If necessary, the contact screws, or the tension screws, if there are any, of the vibrator springs should be adjusted until the vibrators sound alike.

13. The timer should be examined to see that the contact segments are not badly pitted by the spark at the leaving edge. If they are pitted, or if the fiber or hard rubber adjacent to them is roughened by the sparking, the timer should be cleaned up as well as possible with a piece of sandpaper or a file, and the first opportunity taken to true it in a lathe. If the timer is rough, the contact roller or fingers will jump and give very erratic contact when the motor is running fast.

The spark plugs should be unscrewed and their condition examined. It is not necessary to take them apart unless they need cleaning, or unless it is discovered that the porcelain is broken, which will be evident by a looseness of the outer end. If the porcelain is broken and there are spare porcelains at hand, the bushing may be unscrewed and a new porcelain and gasket inserted. Usually, it is impracticable to use the old gasket a second time, as the bushing has to be screwed down so tight as to endanger the porcelain. The bushings should be set down sufficiently to prevent leakage past the porcelain, but no more.

14. The gap between the spark points should not be greater than $\frac{1}{32}$ inch for the best possible spark. The points should be presented directly to each other, and should be filed true and square. The spark will not be so intense if it jumps between needle points. If necessary, the porcelains should be cleaned. To do this properly, it is generally necessary to take the plug apart. The porcelains are cleaned with a cloth or brush wet in gasoline. If the carbon deposit is very hard, it may be loosened with fine emery cloth and the cleaning finished with gasoline and a cloth. In assembling the plug,

care should be taken that the spark points are restored in their correct relation to each other.

15. The battery may be weak and may have to be recharged or replaced. If dry cells are used, it is likely that some of them are weaker than others. The only way to determine this is to use a battery tester, which is a small pocket ammeter through which the cell may be momentarily short-circuited. The battery as a whole may be tested by disconnecting one of the secondary cables from the spark plug and noting the length of the spark in the open air. The spark should be at least $\frac{3}{8}$ inch in length—$\frac{1}{2}$ inch is better. The coil should not be worked with the detached cable held so far from the motor that no spark can jump, as this is liable to tax the insulation of the secondary winding.

16. Having gone over the engine, it may be started, to determine whether the ignition and carbureter adjustments have been made properly. Set the throttle so that the motor does not run excessively fast, and listen to the sounds it makes. Any knocking sound should at once be traced to its source and eliminated. The sound may be due to a loose mud-guard or something of the sort on the car, which of course does not affect the engine. Or it may be found in the loose coupling between the clutch and the gear-shaft, but this coupling is intended to be loose, and will give no trouble. Any knock due to a loose bearing or loose bolt, however, should at once receive attention. It may be found that the motor will run light—that is, without driving the car—and with the throttle nearly closed without developing a knock, but may knock badly when under load. This subject is taken up in *Troubles and Remedies*.

17. The sound of the impulses should be listened to; also the sound of the exhaust at the muffler. If the engine has several cylinders, the impulses should be equally timed and should take place with equal force. If, with the spark somewhat retarded, the impulse is more energetic in one cylinder than another, which may generally be told by the muffled

sound of the explosion, it is either because ignition takes place too early in the cylinder, or because a deposit of carbon in the combustion chamber ignites the charge in its own vicinity immediately after the spark, so that the charge is burning from two points at once and consequently more rapidly than it should. Actual preignition, that is, too-early ignition, due to carbon deposit, seldom occurs when the engine is running light, but may occur when the car is running. If early ignition in one cylinder is due to faulty timer adjustment, the difficulty may be corrected in some one of several ways, according to the construction of the timer. Sometimes the adjustment must be made by filing the contact segments. This should, however, be attempted only as a last resort, after it has become evident that the trouble is not caused by heated carbon in the cylinder, or causes that can be corrected in some other way.

18. If the inlet valves are automatic, they are likely to work unequally when the motor is running light with the throttle nearly closed. Under these conditions, the most careful equalizing of the springs will not prevent one or two cylinders from assuming most of the work, because the force available to open the valves is so small. Often, an engine will run on one or two cylinders for some time in this manner, and then for no apparent reason some other cylinder will start working, and the first will stop. As soon as the throttle is opened, all the cylinders begin to work alike.

19. When the engine is running light, a late ignition in one cylinder will show itself by a louder exhaust from that particular cylinder, owing to the slower combustion of the charge, and consequent higher pressure when the exhaust valve opens. The remedy for late ignition is practically the same as for early ignition, any adjustment of the timer being, of course, in the opposite direction.

20. A quick method of testing the spark timing is as follows: Shut off the gasoline, retard the spark as far as

possible, and open the compression relief cocks. Turn the crank slowly by hand, letting the air escape through the cocks so that the compression will not cause the pistons to run ahead, which would take up the slack between the crank-shaft and the timer, thus giving a false result. Note the position when the vibrator begins to buzz, and mark the rim with chalk or otherwise. Now turn the crank, *always forwards*, until the next vibrator begins to work, and note the flywheel position again. If the engine has four cylinders, or two vertical cylinders with opposite cranks, the new position should be exactly one-half a turn from the old. If the engine has two opposed cylinders, or two vertical cylinders, with the cranks together, the flywheel should have made exactly a complete revolution. If there are three cylinders, the marks on the flywheel should be one-third of the rim circumference apart. Many modern cars have the flywheel rims already marked to indicate the top and bottom positions of the cranks, and these marks may be used, as the spark should occur exactly at the outer or upper dead center when fully retarded.

In case the spark timing is found to be very irregular, it is best to attend to it at once, and in any case irregular timing should not be neglected, as it involves a considerable loss of power.

21. While the motor is running, note whether the cooling water is circulating properly. The motor should be able to run indefinitely with the throttle just open and the spark about one-half advanced, without the radiator heating up excessively, provided that the latter has a fan to assist its cooling. If, on taking the car out on the road, it is found that the radiator is persistently overheated, the cause of such overheating should be investigated. The trouble may be found to be due to a clogged pipe, dirt or oil on the inside or the outside of the radiator, a defective pump, clogged radiator tubes, etc. Before starting, one should always see that there is plenty of water in the radiator, as a deficient supply will cause overheating.

CARE OF THE ENGINES

GENERAL INSTRUCTIONS

22. The ordinary care of a good automobile engine, when everything is working well, is a very simple matter, and comprises hardly anything more than due attention to lubrication, occasional testing of the batteries, with recharging or replacement as required, and seeing that the radiator or water tank is kept full. All the oil supply to the lubricator and oil cups should be strained, though; as the lubricator itself is probably fitted with a strainer, no additional attention at this point is likely to be required beyond occasionally taking out and cleaning the strainer. If any dirt, bits of wood, or fibers of waste get past the strainer, they are liable to make trouble if the oil is fed through any kind of a check-valve or needle valve. Waste is particularly troublesome in this respect, as it shreds and a few fibers of it may very easily get into the oil without being noticed.

23 If the engine is fed from a mechanical oiler, the oil pipes should occasionally be disconnected near the engine, and the engine run or the pump worked by any other available means, to determine if the oil is feeding properly. Most individual pump oilers are operated by eccentrics, which work against stop-screws attached to the plungers, and the stroke of the plungers is adjusted by turning these screws to allow more or less lost motion between them and the eccentrics. The operator should learn, by experimenting with the particular kind of oil he uses, what is the least stroke for each pump that will lubricate the engine properly. If there is any great difference between the strokes thus determined, it is probable that there is leakage, either in the packing around the plunger that demands the longest stroke for the oil feed, or in the check-valves, and this leakage should be investigated at once.

If the oil is not fed to the pistons in sufficient quantity, the engine will make the fact known by a laboring sound and a falling off in power, when both the ignition and the carbureter are in perfect order. If this occurs, a little extra oil may be put into the crank-case, where it will be thrown up into the cylinders in sufficient quantity to ease the engine until the oiler can be readjusted. A new engine should have a little more oil on both pistons and bearings than one that has run several hundred miles, and it is well to feed oil to the former until a little white smoke shows in the exhaust. Black smoke indicates too much gasoline in the mixture.

24. As elsewhere explained, it is best to use the heaviest oil that the weather conditions will permit. Often it will be found that a heavy oil can be used in summer and a medium or light oil substituted in winter without a change of lubricator adjustment, owing to the light oil flowing more freely. Generally, however, an increase in feed is necessary when the lighter oil is substituted.

25. It is well to squirt a few drops of kerosene into each cylinder at the end of a long day's run, say from 75 to 150 miles. This will loosen any carbon deposit that may have formed about the piston rings. Kerosene is a very efficient solvent of the tarry products that act as a binder for this carbon deposit, although, of course, the carbon itself is not dissolved. Most engines have compression relief cocks on the cylinder heads that may be used for introducing the kerosene; but if these are absent the kerosene may be injected through the inlet valves.

26. If the splash system of lubrication is used, and the oil is fed to the crank-case by a hand pump on the dash, this pump should be operated every 25 miles or thereabouts, depending somewhat on the amount of low-gear driving required. Generally there is a shut-off valve between the pump and the crank-case, which is to be opened by hand before the pump is operated.

An improved arrangement that obviates failure of check-valves connected with the hand pump to do their duty consists of a three-way hand valve that in one position admits oil to the pump and in the other permits the oil to pass from the pump to the crank-case. This valve is operated by hand for each stroke of the pump. The pump, of course, is of a fair size, so that two or three strokes are sufficient. Once in, say, 500 miles, all the oil should be drawn off from the crank-case, the case washed out with kerosene, and fresh oil put in, as it gradually fouls from carbon passing the piston, and also gathers grit worn from the bearings.

27. Beyond attention to the lubrication, the daily care required by an automobile engine is simply the brief regular inspection to see that everything is working properly. If a battery is used for ignition purposes, it will need replacement once in a while, and the operator should keep himself informed of the battery's condition by occasional tests, so that he will not be unexpectedly stranded. The tremblers on the spark coils require occasional adjustment, and the operator should notice the sound of each one, and file the contact points square or readjust the springs or contact screws until the sound is correct.

28. Occasionally, the spark plugs will foul and require cleaning or replacement. How often this will occur is altogether a question of the particular carbureter used, lubricating arrangements, and type of plug; and the only general directions that can be given are that the operator should adjust the lubricator and the carbureter to produce as little free carbon as possible in the cylinder, and then should learn by trial how often the plugs require inspection.

29. If the car is used in cold weather, special attention must be given to the lubricating and cooling systems. One item in the daily care of a motor that cannot well be neglected is the listening for knocks or unusual sounds. These

may occur from a great variety of causes, which are fully treated in *Troubles and Remedies*. Nearly all the causes that produce knocking grow rapidly worse if not attended to, and therefore no symptom of this sort should be neglected.

STARTING AND STOPPING

30. The regular order for starting an automobile engine is given in the following paragraphs. This order should be followed every time the engine is started, for this is the best way to avoid forgetting things; in fact, the beginner will do well to memorize these instructions.

1. Open the main gasoline valve at the tank. If the tank is hung low, and the gasoline is lifted to the carbureter by air pressure, ascertain—by priming the carbureter if necessary—that the tank has the required pressure, and pump air into it by hand, if necessary. A hand pump for this purpose is mounted on the dash, usually at the left end. Sometimes the gasoline passes through a small auxiliary tank on the dash, and this tank holds gasoline enough to supply the carbureter by gravity until pressure from the exhaust gases can be raised in the main tank.

2. Retard the spark as far as possible. This is of the first importance, as the attempt to start with the spark advanced may result in a broken arm. It is an excellent rule never to turn the starting crank, even when it is thought that no explosion can occur, without first seeing to it that the spark lever is retarded.

3. Set the throttle about one-quarter open.

4. Close the switch and insert the safety plug, if one is used.

5. Turn on the oil feed. It is assumed that any oiling and filling of oil cups done by hand has already been attended to.

6. Open the compression relief cocks, if there are any.

7. Prime the carbureter, by depressing the float or otherwise, according to its construction. If the motor has been stopped for not more than an hour or two, or sometimes

longer, this is not necessary. If the tank has pressure feed, and the carbureter has been primed to test the pressure (see 1), it does not need to be primed again.

8. Engage the starting crank, and turn it over until the resistance due to the compression stroke is felt. If the starting crank is *not* now on its up stroke, move it backwards a quarter or half turn until it is, and reengage the ratchet at this new point. *Never push* the crank over the compression stroke. Even if the switch is open, a hot motor may start from preignition, and a "back kick" may result in a broken arm.

9. *Pull* the starting crank upwards smartly against the compression. The motor may start. If it does not, turn the starting crank until the next compression stroke comes, and pull it upwards smartly as before.

31. If the carbureter has not been primed too much or too little, the motor should start unless the gasoline is too cold to vaporize. If it does not start with the second or third trial, prime the carbureter again and repeat the operation. If the motor still refuses to start, something may have been neglected or forgotten. It may be that the gasoline is not turned on, that there is no gasoline in the tank, or that it is stale or heavy, that the switch plug is not in place, that the battery is not strong enough, or that the method of priming the carbureter has given too light or too weak a mixture. The method of priming is something that will depend on the individual carbureter, and can only be learned by experience.

32. The procedure for stopping an automobile engine is to partly close the throttle so that the motor will run slowly and then open the switch; if the stop is permanent, take out the safety plug, shut off the oil feed, and shut off the gasoline at the tank. If the car has been run some distance it is well to squirt a small amount of kerosene through the compression relief cocks to loosen any carbon deposit that may have gathered around the piston rings.

ADJUSTMENTS AND REPLACEMENTS

TIMING THE VALVES

33. When a column of gas moves rapidly, as in its passage through the admission or exhaust valves of an engine, it requires considerable force to bring them to rest suddenly. When the force resisting the flow is small, it requires a considerable interval of time to bring the gas to rest. This is very noticeable in engines having automatic valves, in which the force tending to close the valves is small. For this reason, the valve timing of a high-speed automobile engine must be radically different from that appropriate to stationary engines. As the beginning and end of the piston strokes represent considerable crank-angles with very small piston movement, advantage is taken of this fact to hold the valves open for a considerably longer time than would theoretically be required in order to give the maximum opportunity for the movement of the gases.

The exhaust valve should open at a crank-angle between 30° and 40° before the end of the expansion stroke. This represents from one-twelfth to one-ninth of a revolution, and approximately from 5 to 10 per cent. of the piston stroke. It is a common practice, with automobile makers, to mark the flywheel rim with reference to some convenient fixed object, generally the vertical (or horizontal, if the motor be horizontal) center plane of the motor. These marks may indicate the inner and outer dead centers, or they may indicate what the maker has decided is the suitable crank position for the exhaust valves to begin to open. In the latter case, it is generally best to adhere as nearly as possible to the point of opening thus indicated.

34. Although in the majority of automobile engines, the exhaust valves close at the end, or dead center, of the

exhaust stroke, it has been demonstrated conclusively that there is a marked advantage in holding the valves open until the crank is 5° or even 10° past the center. The latter angle represents a piston movement of only about 1 per cent. of the stroke, and no fresh mixture will enter during this period; whereas the prolonged opening of the exhaust valve permits the gases in the exhaust pipe to create a slight suction in the combustion chamber by virtue of their own inertia, thus tending to induce the flow of a larger charge of fresh mixture. If the exhaust valves are held open until the crank is about 10° past the dead center, it is unnecessary to open them quite so early on the expansion stroke as would otherwise be considered necessary. A good average rule is to open the exhaust valves 35°, or practically one-tenth of the circumference of the flywheel before the end, or dead center, of the expansion stroke, thus making the total opening of the exhaust valve about 225° of the revolution of the flywheel. If the engine is to run at speeds upwards of 1,500 revolutions per minute, an earlier opening and later closing may be of advantage.

35. If the inlet valve is located over or beside the exhaust valve, it should open with the crank about 5° past the center. If it is on the opposite side of the engine from the exhaust valve, it may open on the dead center, thus permitting a direct suction across the combustion chamber that will greatly augment the power of the engine. The inlet valve should close about 20° to 30° past the dead center at the end of the suction stroke, or approximately $2\frac{1}{2}$ to 5 per cent. of the piston stroke. The reason for holding open the inlet valve is that at high speeds the inertia of the incoming column of the mixture will carry it into the cylinder after the return stroke has begun.

36. The valve timing is usually adjusted by threaded adjusting ends on the push rods; also, by shifting the two-to-one gear one tooth or more in relation to the pinion. If the total duration of opening of the exhaust valve is less than

230°, after making due allowance for necessary clearance between the push rod and the valve stem, it is advisable to substitute new cams or else to build out the old ones. This can sometimes be done by dovetailing in a segment, as shown in Fig. 2. Generally, it will be necessary to anneal the cams before this can be done. The inserted piece is better located if possible in the closing face of the cam, as it is subjected to less wear on that face than on the other. It should be made of tool steel, and after being tightly driven in and fastened with a rivet or screw, should be hardened with the cam.

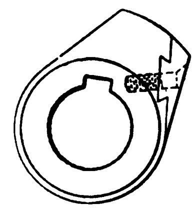


FIG. 2

If the inlet valves are operated by the same shaft as the exhaust valves, it may be impracticable to alter the valve timing by shifting the two-to-one gears. In this case, it will be necessary to alter the cams.

RETIMING THE IGNITION

37. The timing of the ignition may be tested for uniformity by marking the flywheel in the same manner as for timing the valves. In case it is found that the cylinders are unequally timed, the timer should be adjusted according to its construction. If the timer has a cam that presses springs in contact with contact screws, the timing may be modified by adjusting the contact screws so that a little more or less movement of the cam is required to produce contact. If the timer has a fiber barrel *a* with an inlaid copper or brass segment *b*, as shown in Fig. 3, the only way the timing can become incorrect is through wear of the hardened-steel blocks *c*, *c*, at the ends of the contact brushes, or through

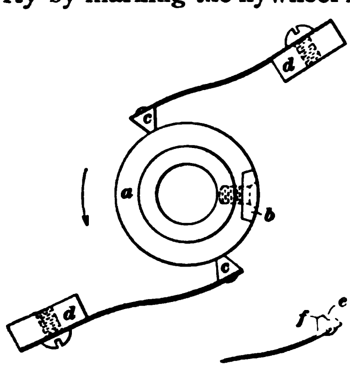


FIG. 3

loosening and slipping of these brushes, which are generally slightly adjustable on their insulated bases *d*, *d*.

When these blocks have worn down considerably, it is well to grind away a portion of their contact surface at the bearing edge, as seen in the detail at *e*, otherwise, considerable pressure will be required to make good contact at the leading edge *f*, and this will wear away the barrel and metal segment unnecessarily fast. When the timing is tested, the spark should always be retarded to its fullest extent, and in this position the spark should occur in each cylinder exactly on, or a definite number of degrees after, the crank has passed the dead center

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REPLACING EXHAUST-VALVE KEYS

38. On account of the inertia of an exhaust valve of an engine running at high speed, the springs that close the valve must be very stiff, and it is sometimes a problem to get them back in place after they have once been taken out—as, for example, to regrind the valve.

To replace the spring, it must first be compressed in a vise and bound securely on opposite sides by two pieces of annealed wire. When this is done, the spring may be put back in place, the valve dropped in, and the washer and key properly inserted. Then the wires binding the spring may be cut with a pair of pliers and the spring allowed to expand. The spring should bear squarely on the washer.

In a few engines, no washer or key is used, but the lower end of the spring itself is bent inwards and flattened to go in a slot in the valve stem. In this case, the spring may be taken out from the valve stem by first blocking up the spring in the same manner as is done when the washer is used, and the spring may be replaced by compressing and binding it as just described, holding the valve in the proper angular position with a screwdriver, while the end of the spring is first pulled and then pushed into position with a strong pair of pliers.

MAKING VALVE-STEM KEYS

39. Valve-stem keys should be made of annealed tool steel, and should not be made too close a fit in the valve-stem slot, because they are likely to bend slightly in use. Ordinarily it is cheaper to buy these keys of the maker of the car than to make them specially. One or two spare keys should always be carried.

TAKING OFF AND REPLACING CYLINDERS

40. In case it becomes necessary to replace the piston rings or to scrape out the combustion chamber, it is necessary to take off the cylinder. If the engine has more than one cylinder, the cylinders are probably marked to identify them severally for replacement. These marks should be looked for, and, if not found, marks should be put on. When the cylinders are off, care should be used to avoid handling the pistons in such a manner as might break their lower edges, which are very thin. When the cylinder is off, it is a good plan to inspect carefully the surface of the cylinder wall and the piston and ring surfaces, to see if they have been scored by lack of oil or water. The cylinders and pistons of a well-kept engine will show a bright, almost mirror-like surface, free from scratches.

41. If the piston rings are clogged with carbon, it is, on the whole, better to clean them as well as possible with kerosene, while in position, rather than to take them off, as the bending of the rings is liable to strain them out of true, and cause leakage when they are replaced. In case it seems advisable to take off the rings, each ring should be marked with a small, sharp prick-punch, and the corresponding groove marked, so that each ring will be restored to its own groove. To take off the rings properly and without risk of straining requires considerable care. A good method is to use three or four narrow strips of tin or thin brass, which are first slipped under the ends of the ring nearest the head,

and gradually worked around until the ring is out of its groove. The same strips are used to bridge the grooves when the other rings are taken out.

When a cylinder is to be replaced, the piston rings must be compressed and tied, else it will be a difficult matter to get the piston into the cylinder. As each ring is started in the cylinder, its binding is removed.

SCRAPING CARBON FROM COMBUSTION CHAMBER

42. A refractory deposit of carbon in the combustion chamber may be loosened with kerosene and scraped out with anything convenient, such as a cold chisel or an old file with the end ground sharp. If it is inconvenient to take off the cylinder, it is frequently possible to remove or reach the carbon through the spark plug or valve holes, the scrapers for this purpose being generally iron rods with the ends flattened and bent to suit the conditions to be met. An exceedingly useful outfit is a battery lamp of 2 or 3 candle-power, with a length of No. 16 lamp cord, by which it may be connected to the battery, and an ordinary plain (not magnifying) dentist's mirror. The lamp is screwed into a miniature socket, and a length of iron wire is wound into a coil around the cord adjacent to the socket, the coil being extended to include the socket and the lamp, thereby forming a protective cage for the latter. It must, however, not touch the lamp.

43. By the use of such a lamp, almost every inch of the combustion chamber of an ordinary engine can be explored and scraped, and the carbon can be pulled out through the spark-plug hole; or, if more convenient, the exhaust valve may be opened and the accumulation allowed to fall into the exhaust port, from which it will be carried to the muffler. It is better, however, to take the exhaust valve right out than simply to open it by the cam, as only in this way can one be sure that none of the carbon lodges between the valve and its seat, thus necessitating regrinding. When the

carbon is scraped out in this manner, it is better not to use kerosene unless it is necessary, as it increases the likelihood

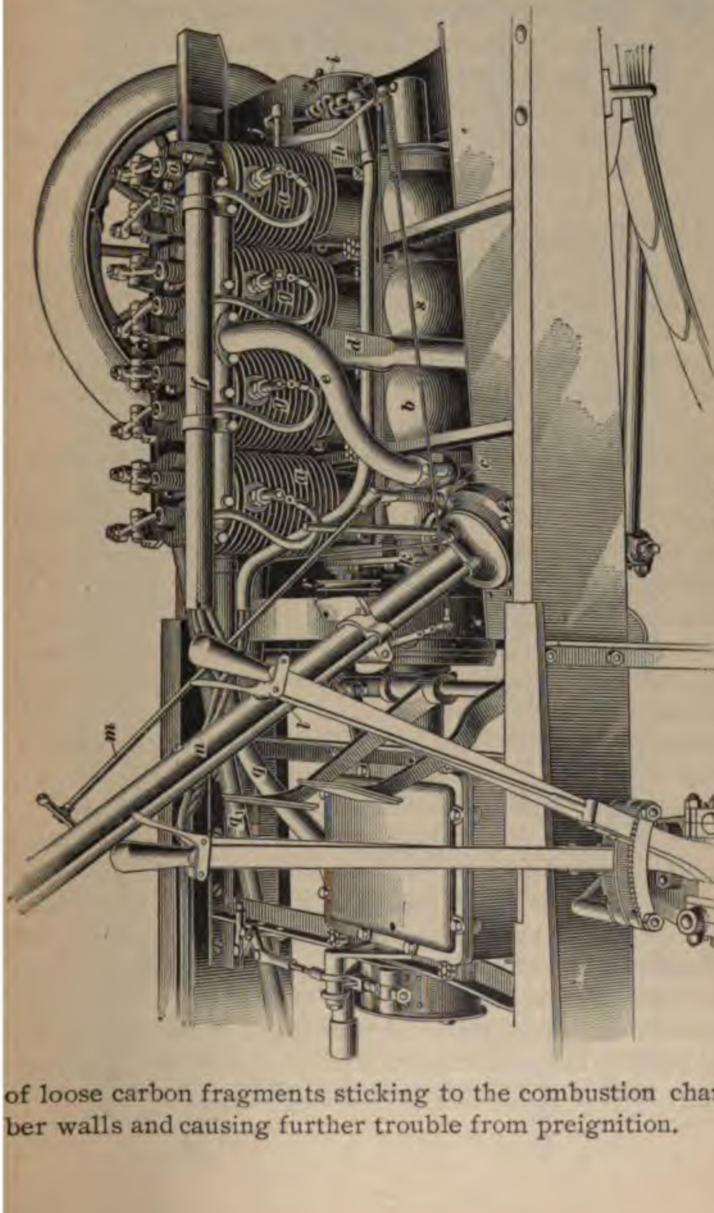


FIG. 4

of loose carbon fragments sticking to the combustion chamber walls and causing further trouble from preignition.

ARRANGEMENT OF ENGINE AND AUXILIARIES

44. Assembly drawings, showing the location of the engine and some of the auxiliaries, are presented in Figs. 4 and 5, the same letters of reference being used to indicate similar parts of both illustrations, which serve to show one of many possible schemes of arrangement. The air-cooled cylinders *a* are bolted to a closed crank-case *b*, supported, as shown, by two angle-iron cross-members of the frame on which the body of the car rests. Air is supplied to the carbureter *c* through the intake pipe *d*; while from the carbureter, the charge passes through the pipe *e* to the supply pipe for the four cylinders. Protection against accidental injury to the secondary cables is afforded by a fiber tube *f*, from openings in which the cables are led to the spark plugs *g*.

The governor on the cam-shaft is enclosed by the casing *h*, in front of which the spark timer *i* is located. The rock-shaft *j*, Fig. 4, controlling the spark time, is operated by the lever j_1, Fig. 5, connection between the spark lever under the steering wheel and the rock-shaft *j* being made by the rods *k* and *l*. Adjustment of the proportions of the explosive mixture is effected by the rod *m*, operated by hand. The steering column is shown at *n*. The exhaust valve *o* and the inlet valve *p*, as well as auxiliary exhaust valves not shown, are mechanically operated by push rods actuated by cams mounted on a single cam-shaft. The auxiliary and main exhaust pipes are shown at *q* and q_1, respectively.

A pulley *r* for operating a mechanical oiling device is mounted on the end of the cam-shaft, as shown. A rod *s*, Fig. 4, operated by the throttle lever *t*, Fig. 5, controls the position of the throttle. The circulation of air over the cylinders is assisted by the use of fan *u*, Fig. 5. The coil box *v* and the mechanical oiler *w* are mounted on the dash, as shown in Fig. 5, the battery boxes *x*, *x*, being carried on the steps. The transmission gearing is enclosed in the casing *y*, outside of which is located a brake *z*.

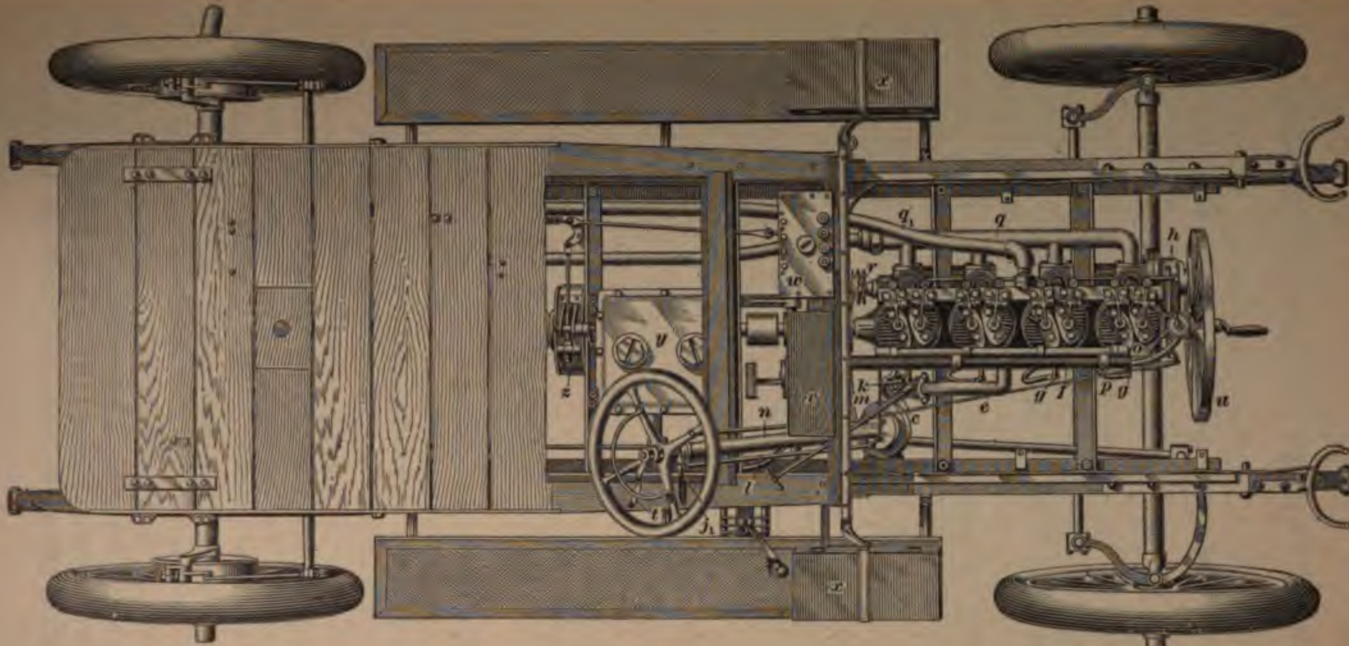


Fig. 5

MISCELLANEOUS SUGGESTIONS

COLD-WEATHER HINTS

45. In cold weather, the circulating water, the oil, and the carbureter, require special attention. If the car is to be run regularly during the winter, it is advisable to use a non-freezing mixture in the water-jacket. If the car is not to be used regularly, it may not be necessary to employ such a mixture, but in that case great care is necessary to prevent the water from freezing unexpectedly. If the car is kept in a barn, the water should be drawn off completely after the car has been used, and the drainage cock should be so located and the piping so arranged that there are no water pockets in which the water may freeze and obstruct the circulation. If the water freezes in the pump, the latter is likely to be broken when the car is started the next morning. If water freezes in the water-jackets, it will burst the jackets unless they are made of copper. When the car is left standing for an hour or so, cloths or lap robes may be thrown over the radiator to check the cooling; this is cheaper and safer than leaving the motor running.

46. The two substances most used to prevent freezing are glycerine and calcium chloride. A 30-per-cent. solution of glycerine in water freezes at 21° F.; and a solution of one part of glycerine to two parts of water is safe from freezing at 10° or 15° F.; 40-per-cent. solution freezes at zero. A small amount of slaked lime should be added to neutralize any acidity in the solution. Glycerine has the objection that it destroys rubber, and the solution fouls rather quickly.

A cheaper mixture, and one preferable where the temperatures encountered are likely to be below 15° or 20° F., is a solution of calcium chloride. This must be carefully distinguished from *chloride of lime* (bleaching powder), which is injurious to metal surfaces. Calcium chloride costs about 8 cents a pound in bulk, and does not materially affect

metals except zinc. A saturated solution is first made by adding about 15 pounds of the chloride to 1 gallon of water, making a total of about 2 gallons. Some undissolved crystals should remain at the bottom as evidence that the solution is saturated. To this solution is added from 2 to 3 gallons of water, the former making what is called a 50-per-cent. solution. A little lime is added to neutralize acidity. A 50-per-cent. solution freezes at − 15° F.

47. Whether glycerine or calcium chloride is used, loss by evaporation should be made up by adding pure water, and loss through leakage by adding fresh solution. In using the chloride, it is important to prevent the solution from approaching the point of saturation, as the chloride will then crystallize out and clog the radiator, besides boiling, and failing to cool the motor. A 50-per-cent. solution has a specific gravity of 1.21, and should be tested occasionally by means of a storage-battery hydrometer. Equally important is it to prevent the water from approaching the boiling point, whatever the density, as boiling liberates free hydrochloric acid, which at once attacks the metal of the radiator and cylinders.

A solution of two parts of glycerine, one part of water, and one part of wood alcohol has been recommended, which is said to withstand about zero temperature.

48. Certain mineral oils used for the lubrication of refrigerating machinery are recommended for cooling, because they remain liquid at very low temperatures. They are not particularly good heat conductors, however, and will not keep the motor as cool as the water solution. If the oil is used, it must be cleaned from the radiator by the use of kerosene and oil soap, before water can again be used effectively.

49. As regards lubrication, the principal danger is that the oil will thicken from the cold so that it will refuse to feed. This is avoided by using *cold test oil*, which remains liquid at lower temperatures than ordinary oil, or by adding to the ordinary oil some kerosene or gasoline, and increasing the feed. If the oil tank is located close to the engine, it

will remain warm even in quite cold weather; but, unle the car has been kept in a warm place over night, the bea ings are liable to run dry before the car has warmed up.

50. The temperature has a very marked effect on t rapidity with which gasoline vaporizes, and in cold weath it is necessary to supply heat to the carbureter. The ca bureter should preferably be jacketed, and it may warmed either from the circulating water or by taking small quantity of the hot gases from the exhaust pipe. water is used, it should be taken from a point just beyond t discharge of the pump, and should be delivered to the retu pipe from the engine jacket to the radiator. Wheth exhaust gases or water is used, the flow shonld be regulat by a cock, otherwise too much heat will be received in war weather.

When the carbureter is cold, the engine may be starte by pouring warm water over it, care being taken not to le the water get into the gasoline through any aperture in th top; or cloths may be wrung out in hot water and wrappe around the carbureter. Fire of any sort should never b used.

GASOLINE-HANDLING PRECAUTIONS

51. The user of gasoline should never forget that it is the liquid gasoline, nor yet the vapor of gasoline, tha explosive, but only the mixture of gasoline vapor and ai the right proportions. If the liquid gasoline were nc volatile, it would be as safe to handle as kerosene, in v one may plunge a lighted match without igniting it, the r instead being extinguished by the cold oil. But since ga evaporates rapidly when exposed to the air, it is not e to avoid bringing a lighted match, a flame, or an e spark within the vicinity of the liquid—as, for exampl gasoline has been spilled on the floor or on the grou one must also avoid any possible source of ignition a in the neighborhood until the air has changed suffic dilute the vapor below the point of inflammability.

11 the accidents due to the handling of gasoline arise simply rom carelessness in neglecting these precautions.

52. Air saturated with the vapor of gasoline will burn f allowed to come in contact with fresh air, but it will not xplode, as the proportion of gasoline vapor in it is too great. t follows that a can or tank containing gasoline is safe from xplosion if the vapor of the liquid is saturated, and this is he condition that will naturally obtain if the liquid has been lrawn off so gradually that its place has been filled with air ind saturated vapor. If, on the other hand, the can or tank ias been emptied quickly, air will enter it to take the place of the liquid poured out, and the proportion of vapor will not be sufficient to prevent it from being explosive. This is the most dangerous condition possible, and calls for the strictest precautions to prevent the ignition of the mixture therein.

MANAGEMENT OF MARINE GAS ENGINES

MARINE-ENGINE INSTALLATION

LOCATION OF ENGINE AND AUXILIARIES

1. An installation diagram such as is shown in Fig. 1 serves the double purpose of guide and working plan, indicating the position of the engine and showing the location and arrangement of the accessory apparatus forming part of the power equipment.

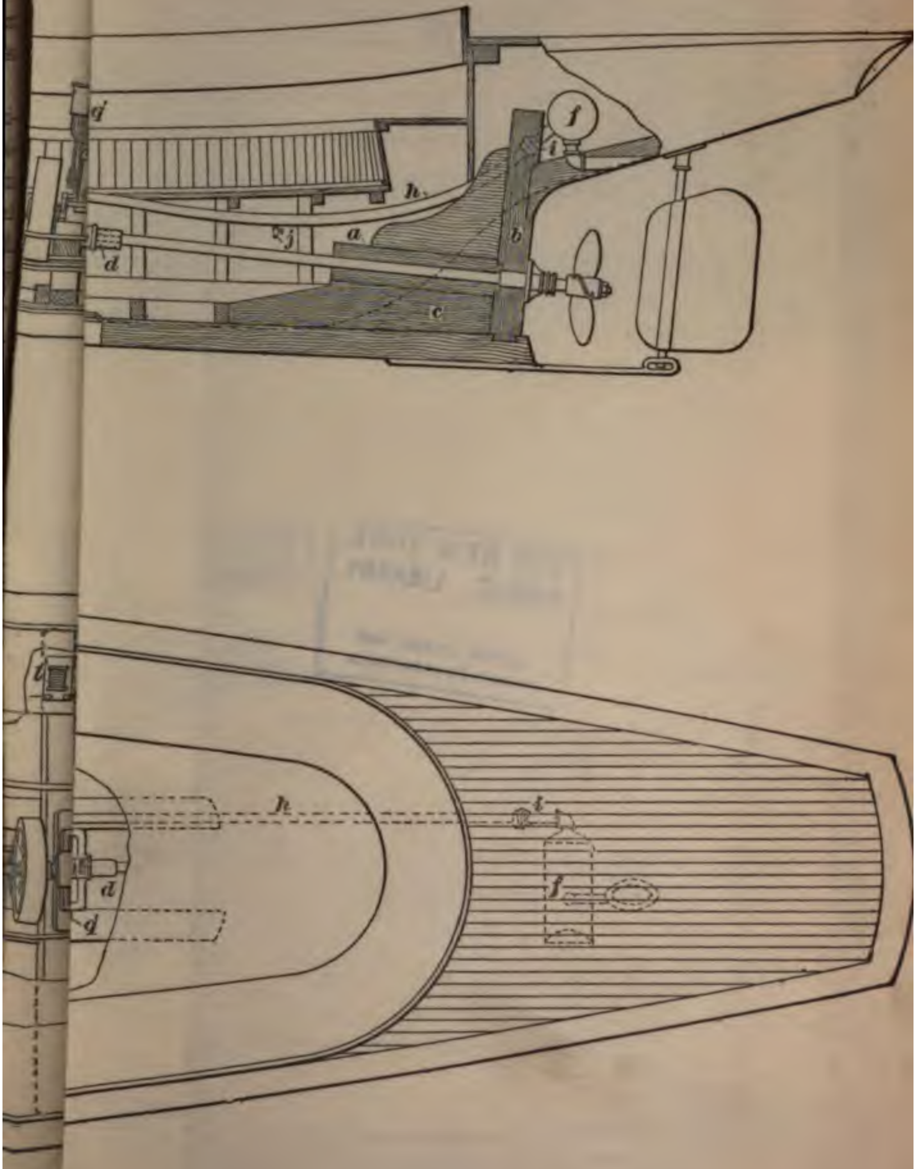
Among those parts to which subsequent reference will be made in the text are the shaft log *a*, stern post *b*, dead wood *c*, compression coupling *d*, sea cock *e*, muffler *f*, and gasoline-supply tank *g*. Other parts to which no specific reference will subsequently be made are as follows: engine exhaust pipe *h* leading from the engine to the muffler *f* and connected up by means of two unions *i*, *i* and an elbow, a petcock *j* being located at the lowest point in the pipe; battery *k* and spark coil *l*, Fig. 1 (*b*); outboard gasoline-supply pipe *m*, Fig. 1 (*a*), from supply tank *g* to carbureter *n*. Fig. 1 (*b*); reverse rod *o* for forward, or bow, control, consisting of a galvanized-iron pipe with ends shaped for connection to the reverse-gear mechanism and to the lower end of the reverse lever, which is held in the bracket *p*, the lever *q* being the regular reverse lever, which for use in the bow of the boat can be removed from its usual position at *q'* on the gear-case *r*; air pipe *s* leading to the whistle tank *t*,

to which the signal whistle is attached; brass strainer *u* on the outlet pipe in the gasoline tank; hand wheel *v* for operating the valve in the gasoline-supply pipe; and brass tank plate *w*, provided with two small vent holes.

To install a marine gasoline engine so as to insure maximum safety and freedom from excessive vibration necessitates a thorough understanding of all the requirements to be met, including the construction and location of the fuel tanks, engine, carbureter, piping, etc., and also a thorough knowledge of the operation of the engine. Before any attempt is made to install the engine, there should be provided a working blueprint or drawing, indicating the distance from the center line of the crank-shaft of the engine to the under side of the bed or lugs, giving all the dimensions and showing plainly the outline of the base below the bearing side of the lugs. A drawing of the longitudinal and athwartship, or crosswise, pieces, with the dimensions plainly marked, should accompany the drawing of the engine base.

2. When the boat is new, the shaft hole is usually bored before the shaft log *a* and the stern post *b*, Fig. 1 (*a*), are put in place; if, however, it is necessary to bore the shaft-hole, the work should be intrusted to some one of experience, as it sometimes becomes necessary to make important changes in order not to weaken the boat or render it unsafe.

If the shaft hole has been bored, a line should be run from the center of the outboard, or outer, end, in the direction to be occupied by the center of the propeller shaft, to a point considerably beyond where the front of the engine will come. From this line, measurements should then be made to determine whether or not there is sufficient room for the engine, reversing gear, flywheel, etc. To obviate any chance of error, the measurements on the diagram or drawing should be verified by measuring the engine, so that, when once in place, the engine need not be removed. There is usually a keelson *a*, Fig. 2, a timber running the whole length of the boat and fastened to the



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keel *b* over the ribs *c*, Figs. 2 and 3. For the purpose of strengthening and stiffening the frame, the ribs are also frequently fastened to similar pieces, called *bilge keelsons*,

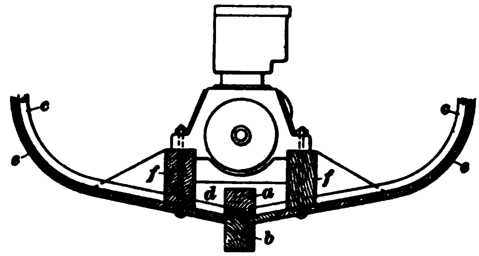


FIG. 2

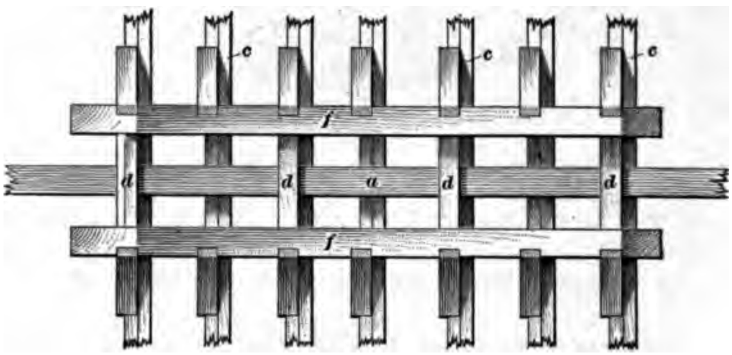
running lengthwise of the boat. If hauled out of the water, the boat should now be leveled up. A plumb-bob dropped from the above-mentioned line at its forward end should mark the center line of the keel or of the dead wood *c*.

3. Transverse pieces of oak *d*, Fig. 2, of sufficient thickness should be let down to the planking *e*, fitting closely over the keelson, and securely bolted into or through the keel and fastened to the planking and to the timbers, as shown in Fig. 2, which serves to illustrate one method of placing engine-foundation timbers. The timbers *d*, when fitted to the bottom of the boat and securely fastened to the planking, sometimes serve to form bulkheads, or partitions, extending all the way across the boat. Figs. 2 and 3 show the transverse pieces let down between two timbers *f*, *f* running fore and aft, or lengthwise, and serving as the foundation through which the stresses set up by the engine are distributed throughout the whole bottom surface of the boat, thus lessening the vibration.

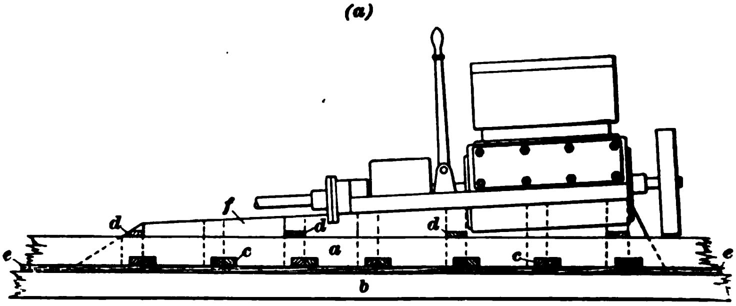
At the lowest points on both sides of the keelson, *limbers*, or small spaces between the planking and ribs, should be cut to allow water to pass through; or some means should be provided to pump out from each compartment separately any water that may collect there. When the latter and the safer method is employed the bulkheads should be made

water-tight, the lower edges being bedded in red-lead or white-lead putty.

If there are two or more compartments under the engine, they should be connected so that drippings of oil from the engine and gasoline from possible leaks at the carbureter may collect there, to be pumped out by hand or with a pump operated by the engine. This method of disposing of



(a)



(b)

FIG. 3

drippings is better than having no drip pan under the engine, and in a cabin boat should always be used even with a drip pan under the engine; otherwise, an accumulation of gas in the cabin space is liable to be ignited and to explode with grave results.

With a twin-screw installation using two separate engines, the longitudinal timbers on which the engines rest may be

let down a little way into the bulkheads and cut away slightly, so that the bulkheads themselves may securely support the longitudinals, which may have to be cut away or entirely cut off to allow room for the flywheel, but the longer they are the better. Almost any hard wood will do, but nothing is better than good sound oak.

4. The size of lumber used in engine beds depends entirely on the engine. The ordinary single-cylinder engine requires a heavier bed than almost any other, except a two-cylinder, four-cycle engine with cranks 180° apart. Sometimes, single-cylinder engines are constructed with what are known as **counterweights** attached to the crank-shaft on the side opposite to the crankpin or to the flywheel in a similar position, the object being to balance the weight of the piston, crank, and connecting-rod. When balance weights are employed, it is not necessary that the bed construction should be quite so heavy. With four-cycle engines, even with counterweights, beds should be more substantial than for two-cycle engines, as the explosions do not occur so often, and, being more powerful, are more likely to cause excessive vibration.

Double-cylinder four-cycle engines with cranks opposite, or 180° apart, require an engine bed of the heaviest construction, because there are two impulses during one complete revolution of the crank-shaft, the explosion in the second cylinder following closely upon that in the first, accelerating the crank-shaft speed; a complete idle revolution follows; the latter half of the revolution, being against the compression, causes a particularly unpleasant vibration that, unless absorbed by the engine bed or the boat itself, may be unsafe because of the light construction of the boat or the presence of some defect. Two-cycle engines of two or more cylinders and four-cycle engines of three or more cylinders are better balanced and do not require such heavy beds.

5. In some cases, it has been found necessary to put in braces from the top of the engine to the side of the boat, the

engine bed and lower part of the hull being too light. It is customary to make the hull where the engine is to be placed of much heavier construction by putting in a double framing of extra or heavier ribs. Weak engine beds may sometimes be strengthened materially by filling in about the timbers with Portland cement and sharp sand.

It is rarely found necessary and is hardly advisable to fasten engine beds through the ribs and planking, as is often done in marine steam-engine practice, for such fastening tends to weaken the hull construction instead of strengthening it.

A drip pan of good depth under the engine is necessary for catching all dripping oil, and, if connected to another pan under the carbureter, gasoline that may leak there will be prevented from getting into the hull of the boat, running into the drip pan instead, from which place it may readily be pumped out. This drip pan should be fitted under the base of the engine and to the hull before the engine is in place. The edges should be flanged over the longitudinal pieces of the engine bed, which should be cut away so that the engine base will not bear on the edges of the drip pan. Copper makes the best material for a drip pan, but galvanized iron may be used in fresh water only, the outside of the tank being well protected with asphaltum varnish.

6. Before placing the engine on the bed, be sure that the two longitudinal timbers are not in *wind*, that is, with the end of one higher than the same end of the other. This would make the engine rest like a four-legged chair with one short leg. To determine whether or not there is wind to the bed, place a level squarely across both forward and after ends, or build up the after ends alike until they are both level, and see whether or not both longitudinal pieces are true. A little variation from a true level will make quite a difference in the character of the stresses set up when the engine is in place and operating. It may be necessary to cut away a part of one or more of the bulkheads to make room for the base or reversing gear.

If, having the engine on the bed, the engine base is

continued to support the reverse gear *r*, Fig. 1, put in the propeller shaft, put on the stuffingbox and separate stern bearing if one is used, and, if the propeller shaft is to be coupled by means of a sleeve coupling, see that the ends of the shaft project into each end half way, with the key removed, and that the propeller shaft turns freely. If a compression coupling *d*, Fig. 1, is used, see that both shafts are in line. If the two shafts are flanged, see that they come fairly together, moving the engine slightly, if necessary, in order to get the shafts absolutely in line, and blocking up the forward or after end of the engine, if necessary, being particular that the propeller shaft does not touch the side of the lead sleeve in the shaft log *a*, Fig. 1. If a brass sleeve is used, it should not be fastened until the engine is lined up, as stern bearings and stuffingboxes are usually screwed into the brass sleeve. Lead sleeves are usually considerably larger than the shaft; their ends are flanged over and copper-nailed, after being bedded in putty consisting of white lead stiffened to the proper consistency with red lead. Where no sleeves at all or lead sleeves are used, stern bearings and stuffingboxes should be fastened flush with the ends of the shaft log, by means of bronze screws

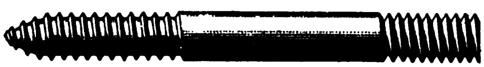


FIG. 4

when the stuffingboxes and stern bearings are of bronze, and by means of iron or steel screws when iron stern bearings are to be used. Iron or steel stern bearings should never be used around salt water, except with very large shafts, lignum-vitæ bushed stern bearings and bronze bushings always being used on steel shafts. While bronze lag or coach screws as sent out from the factories are usually employed, a much better custom is to use bronze studs with a wood-screw thread on one end and a bolt thread on the other, as in Fig. 4. These studs can be screwed into place by screwing on a nut half its thickness and screwing

another stud down hard against the first, as in Fig. 5. A stud driver Fig. 6 may also be used. This consists of a square or hexagonal piece of metal *a*, threaded as shown to receive the machine-screw end of the stud *b*, which is locked in place by the capscrew *c* while the wood-screw end is being screwed into place. One special precaution to be

FIG. 5

FIG. 6

observed in fastening all stern bearings and stuffingboxes is to see that they rest squarely against the wood and that a thin layer of red-lead putty is placed between the metal and the wood, the metal being drawn into place so that it does not bind the shaft.

7. Small engines are usually fastened to their beds by iron screws, but a more satisfactory fastening will be found in steel or iron studs, similar to the bronze ones used for fastening the stern bearing and stuffingbox. In case of necessity, it will be found much easier to remove a few nuts than to remove the coach screws, especially after they have been in place a year or so. When it becomes necessary to line up an engine with a separate reversing gear, the shaft of the latter should be sufficiently long to extend from the after bearings to the crank-shaft. After lining up the crank and propeller shafts, a temporary bearing should be erected abaft the reversing gear, which is usually supported with a thrust, the gear shaft then being lined up with the crank and propeller shafts and securely fastened.

If it is found necessary to raise either end or side of the engine to line it with the shaft, thin pieces of iron or tin will be found very convenient, or thin pieces of hard wood may be used.

8. In case the flywheel is shipped separately, or has to be removed to get the engine into place, it should, if bored

straight and the key driven in, be replaced carefully in exactly the right position, noting that the key rubs on all four sides by taking it out two or three times after starting to see that it fits. If the flywheel is fitted on a taper, as is sometimes the case, care should be exercised that the key does not prevent the wheel from going into its proper position on the shaft because of its being too thick or being placed wrong side up. Flywheel keys should always fit on both sides as well as top and bottom, and should be oiled before being driven into place. Occasionally, a flywheel and a crank-shaft are found in which the keyways are cut a **V** shape and extreme care should be used in driving in the key, for there is great liability of splitting the hub of the flywheel.

The fastening of flywheels securely to the crank-shaft is such an important matter that some manufacturers make the crank-shafts with a flange on the flywheel end, the flange being bolted to a web in the flywheel.

9. In some cases it will be found necessary to take the engine apart more or less to get it through a companionway or skylight. If the operator or other person making the installation has had much experience with machinery, he will observe much caution in taking it apart, marking each piece, usually with a center punch, so that each gear will mesh with the same teeth when putting together again, and each part will go back to its proper place. For thus marking the parts, a center punch and a light hammer will be found indispensable.

10. The alinement of the engine and propeller shafts is an important proceeding, more particularly if no universal coupling is used. In extremely light boats, as in yacht tenders, and when using engines designed to be installed level or more nearly level than the propeller shafts, universal couplings are necessary. They are of numerous forms and of varying utility; the greater the angle between the two shafts thus connected, the more unsatisfactory is their use. While the engine and propeller shafts are being lined up, the boat

should be blocked up evenly along her keel. No matter how carefully the work of lining the shafts may be done, it will be necessary to reline them after the boat has been put in the water and has assumed her normal shape. When the engine shaft is in line with the propeller shaft and the stern bearing and stuffingbox are securely fastened, the engine should be fastened to the bed, after which the water and exhaust piping may receive attention.

PIPING AND GASOLINE TANKS

PIPING

11. In piping up for the circulating water, care should be exercised that leaks do not develop at the sea cock *e*, Fig. 1 (*a*), where the water from the outside enters the boat. The usual method of making the sea-cock connection is to use a long brass nipple, with a locknut outside and inside, and with washers underneath. In some cases, the water connection is arranged as shown in Fig. 7; it is put through from the outside of the plank, with a brass washer *a* under the

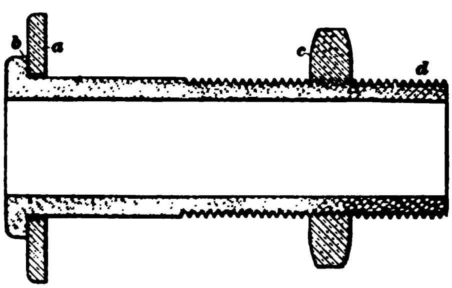


FIG. 7

shoulder *b*, the whole being held in place by a brass locknu with wooden washers underneath it. The water piping then screwed to the inner end. A much safer method co sists of fitting to the inside of the planking a block of wood t or three times as thick as the planking. The block is bedd

in putty, and is then carefully and solidly fastened to the planking. A hole just large enough to admit of passing through it a piece of lead pipe of good thickness, and having a clear way fully as large as the inside of the pipe to be used for the water suction, is then bored through the block and planking. The hole should be chamfered outside and inside. One end of the lead pipe should be flanged out and hammered into the chamfered edge at the inner end of the hole in the pipe, being cut off about ½ inch beyond the outer end of the hole. Then holding in place the inner end, the outer end should be flanged over and nailed with copper nails spaced rather closely, being sure to have white or red lead under the flanges. A brass railing flange can now be screwed to the end of a short annealed-brass nipple, which

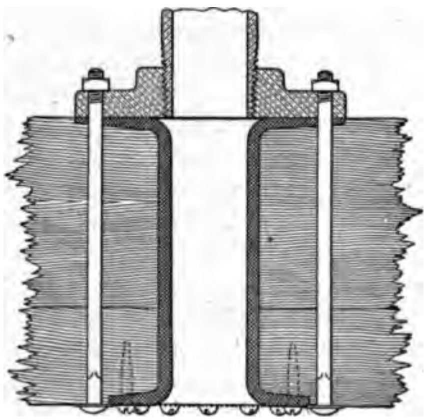


FIG. 8

had better be soldered in to obviate danger of unscrewing in case it should ever be necessary to remove the piping, stopcock, or valve attached to this nipple. The flange should then be bolted against the inside end of the lead pipe, as shown in Fig. 8, using button-head brass bolts, which pass through the outside planking. If long brass wood screws are used, they should be cut off outside the planking. The piping should be led to the pump suction, using two or three regular or 45° elbows, and a sufficient length of piping

and number of fittings to take up vibration without causing leaks or other injury to the planking. Rubber hose is sometimes used; but, unless the piping is led to a point higher than the water-line, and kept above it, a leak might fill the boat with water.

Whether a reciprocating or rotary pump is used, there should always be a check-valve close to the suction end of the pump to keep water in the pump and engine cylinders when the engine is not running; otherwise it would be necessary to prime the pump when starting, and the cylinders would remain hot for a long time after stopping. For use in cold weather, it is necessary that means be provided for draining the water piping to prevent freezing of the water and consequent injury to the piping and water-jacket. The piping between the pump and the engine is usually provided and put in place by the manufacturer, but if no means of draining it is provided drip cocks should be put in.

Outside the hull, where the circulating water is taken in through the sea cock, there should be a flat copper or brass strainer to prevent grass or other foreign matter from being drawn into the pump or from stopping the action of the check-valves. The holes in the strainer should be fairly close together, and about $\frac{3}{16}$ inch in diameter. The metal should be fairly heavy, and the strainer should be securely fastened to the hull by means of small brass screws.

12. The discharge water piping in a multicylinder engine should always lead from the highest part of the engine, that is, from the forward instead of the after cylinder. In order to avoid danger of bursting the cylinder, no valve should ever be placed in the discharge piping. The best method is to branch the discharge, running one pipe into the engine exhaust pipe and the other outboard, the outboard branch being provided with a square-headed cock. As there is always a certain amount of pressure in the engine exhaust pipe, the discharge water would naturally flow more freely through the outboard branch and cock; but a part of the discharge water may readily be diverted to the engine exhaust from the outboard

discharge pipe by partly closing the cock. If conditions were such that too much water was diverted to the engine exhaust, and if it were found impossible to reduce the amount of water by means of the cock in the outboard discharge branch, the cock should be placed in the branch to the engine exhaust, being removed from the outboard discharge, lest by any chance both discharges should be closed, in which case the pressure created by the water pump might burst the water-jacket.

13. When it is necessary to install an engine with the top of the cylinder lower than the water outside the boat, extreme care should be exercised that the discharge water does not get back into the cylinder through the engine exhaust by way of the exhaust valves or ports. One of the best methods is to water-jacket the engine exhaust pipe, the water-jacketing pipe being led outboard or run to the muffler or to the highest part of the exhaust piping where the water cannot run back to the engine. Under no conditions should engines constructed so that a part or all of the jacket water is discharged around the engine exhaust be installed with the top of the cylinder below the water-line, unless some means is devised to prevent the water discharged into the jacket about the exhaust from entering the cylinder through the exhaust pipe. The water from the cylinder head is sometimes discharged into a space about the muffler, the water entering the exhaust piping when it reaches a certain height.

Attempts have been made to overcome the difficulty due to the passage of water from the exhaust pipe to the engine cylinder, by placing a valve in the branch to the exhaust pipe, closing the valve when the engine stops and opening it when the engine starts. As a result of forgetting to open this valve, the exhaust pipe and muffler may set the boat afire; and were the operator to forget to close it, the cylinders may fill with water. If the exhaust pipe can be run high enough at the engine to drain away from it, the jacket water may safely be discharged into it at this high point; but it is

best not to run water into the exhaust pipe, an inside water-jacketed exhaust or outside cooling method being preferable.

14. The best location for the sea cock, or water intake, is a few inches below the water-line, for at that point the cock is less liable to get clogged with sand or grass. With a good strainer over it, it can easily be reached and cleaned. If, however, the boat is what is known as an *auxiliary*, that is, a boat intended to be propelled by both sail and power, it is a good plan to locate the sea cock lower down, in order to be sure that it will always be submerged.

In reducing the amount of water thrown by the pump, it is always best to throttle it at the suction, never at the discharge.

Another thing to remember is that the water piping should be run so as to avoid any possibility of flooding the boat through siphonic action.

15. For use in salt water, the piping should be of annealed brass, which is easier to install and safer because of freedom from corrosion. Sharp turns in piping are to be avoided where possible, and the use of 45° elbows instead of the regulation 90° elbows is always advisable.

In sight, and at places handy to get at, malleable-iron fittings should be used; but out of sight, and in close quarters, cast-iron fittings will be found better, because they can easily be broken, especially if it is ever necessary to take down the exhaust piping. It is always advisable to use plenty of graphite and cylinder oil in making up exhaust-pipe joints. Flanged unions will be found preferable to ordinary malleable-iron unions, for it will usually be found easier to cut off the flange bolts than to take down a screwed union after it has been used a season. Graphite and cylinder oil or graphite pipe grease will be found better than red or white lead in making up joints in the water piping.

16. The engine exhaust may be piped outboard in many ways, the simplest being to pipe it directly through a muffler

arranged vertically. While simple, this plan is not often adopted. A dummy stack makes an excellent place for an exhaust, but it would not be safe or expedient to run jacket water into it, because the water would run back into the engine. In many open launches, it is found quite convenient to exhaust through one or both sides of the boat. In most cases, especially in auxiliaries, the exhaust should issue at or above the water-line. Some boats, however, are provided with an under-water exhaust. With four-cycle engines, it is usually customary to vent the exhaust piping at a point considerably higher than the water-line, in order to prevent water from siphoning back to the engine. Siphoning is much more liable to take place with engines using positive inlet valves than with those using automatic inlet valves, for the reason that, when an engine of the four-cycle type stops, the exhaust piping, muffler, and combustion chamber are usually filled with hot gases and steam. These condense, creating a partial vacuum, and if the exhaust valve is off its seat, as it is on the exhaust stroke, and the inlet valve is held to its seat, water from the exhaust pipe is liable to be drawn into the cylinder or into the valve chamber, rusting the exhaust-valve stem and thus causing it to stick. In a two-cycle engine siphoning would not be so likely to occur, because as the hot gases and steam condense and the exhaust port is open, the passover port also would be open, thus relieving the vacuum.

Mufflers should be piped so that the exhaust enters the upper side or upper part of the end, leaving at the lower end, and draining outboard, as shown at *f*, Fig. 1.

17. One of the chief dangers from fire in boats propelled by gasoline engines, whose exhaust piping is not water-cooled, is from overheated exhausts. These fires are easily discovered, and if the gasoline tanks are not located near the exhaust piping, there is very little danger of burning up the boat. In all cases the exhaust piping and muffler, unless cooled, should be protected with sheets of asbestos board securely bound on with wires or metal straps or some

similar pipe covering. The exhaust pipe should extend ½ inch or more through the planking, to prevent iron rust or soot from staining the paint.

GASOLINE TANKS

18. The safest location for the gasoline tank *g*, Fig. 1, is in the bow of the boat in a water-tight compartment. Some manufacturers make a practice of using a drip pan of liberal height under the tank, connecting the two lower after corners with the outside by means of scuppers or openings through which it may drain when the drip pan is located above the water-line; otherwise, means are provided for pumping accumulations of water or gasoline from the water-tight compartment. Some objection may be made that the difference in weight of a full or empty tank affects the trim of the boat, but this objection is trivial compared with the advantage of safety. When tanks cannot be placed in the bow, it is allowable to locate them on deck or in the cockpit, in the open place in the stern, or under the seats. In both of the last two places, the drip-pan system with outboard drainage should always be employed.

19. The material from which tanks are made differs with their capacity. Tanks up to 40 or 50 gallons, made to fit the contour of the boat and located in the bow, or under the seats in the cockpit, should be constructed of hot-rolled or soft-rolled copper tinned on the inside. For the larger sizes, no less thickness than that weighing from 30 to 36 ounces to the square foot should be employed; while for smaller sizes of from 10 to 15 gallons capacity, 24-ounce copper should be the lightest allowable. The tanks should be double-seamed, as shown at *a*, Fig. 9, on all edges except the top, which may be a single seam, as shown at *b*, both

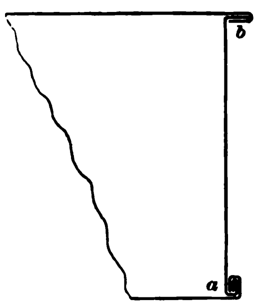


FIG. 9

seams being carefully soldered. Longitudinal and transverse partitions, or **swash plates,** should be provided, so that there may be in the tank no spaces larger than 12 inches in either length or width. Thus, for a tank 18 inches wide and 4 feet 3 inches long, there should be one longitudinal and four transverse partitions.

The object of these partitions or swash plates is to prevent the contents of the tank from rushing from end to end of the tank and also to support, or stay, the sides and bottom. An unobstructed movement or swashing of the gasoline would be liable to dislocate the tank, break the gasoline piping or tank connections, or stir up water or sediment that might be present in the tank and cause a clogging of the carbureter or vaporizer. Even though the longitudinal partitions may sometimes be omitted the transverse plates should not be left out under any pretext. They should be riveted to the bottom and sides of the tank, and, to prevent electrolysis in case salt water should ever be present, should be of the same material as the remainder of the tank. Apertures should be cut at the bottom to allow a free passage of the contents from one compartment to another. The top of the tank should be crowned slightly to prevent the accumulation of gasoline or water.

20. Before the top is put on, the connections should be made for the gasoline supply and drain to the tank. Where these connections are to be made, the sides should be reinforced by copper of the same thickness as the tank, projecting several inches above and to each side. These reinforcing pieces should be riveted and soldered or sweated to the side or the end of the tank rather than to the bottom. The supply-pipe connection should be 2 or 3 inches higher than the drain-pipe connection. The supply-pipe connection should be of not less than $\frac{3}{8}$-inch iron-pipe size, seamless, soft-copper or brass pipe, with two locknuts and washers—one nut and washer on the inside and another on the outside—the whole being sweated together with soft solder. The object of thus soldering the connections is to prevent loosening

them in connecting or disconnecting the valve or supply piping.

21. The gasoline tank and the drip pan should be connected together rigidly, so that the tank will not slide around in the drip pan. The supply pipe should pass through a stuffingbox either at the top or at the bottom of the side of the drip pan. There should also be a stuffingbox where the supply pipe passes through the hull in case outside piping is used, or through the water-tight bulkhead in case it is decided to use inside piping. All piping for gasoline should be of ample proportions, never less than ¼ inch, preferably ⅜ inch, iron-pipe size, and should be of soft, seamless copper or annealed brass, preferably the former; under no circumstances should lead or block-tin piping be used, because of liability of leaks due to breaks caused by vibration. With lead and tin piping there is also considerable uncertainty as to whether or not the brass nipples used are soldered properly. A screwed and soldered joint is much safer than a plain soldered one.

Where the outside piping enters the boat, another stuffingbox or similar contrivance should be employed. The supply pipe should enter as near the carbureter as practicable, and between the carbureter and its entrance there should be interposed a helically wound coil to take up vibration and prevent stress on the piping where it enters the boat. Breakage at this point is accompanied with grave danger, and on this account the piping should at all times be protected against possible contact with ballast or anything liable to injure or rupture it.

Stop-cocks should be placed close to the tank, and also between the carbureter and the point where the piping enters the hull. Outside piping should be protected by a bronze shoe where it passes through the planking at the bow, and with a grooved piece of oak put on with brass screws and extending the whole length of the outside pipe.

22. Gasoline filling pipes and vents to the tanks are very important features and frequently get little attention.

If the filling pipe extends several inches into the tank, and small vent holes are drilled in it, as in Fig. 10, just below the top, when filling with a long funnel that extends

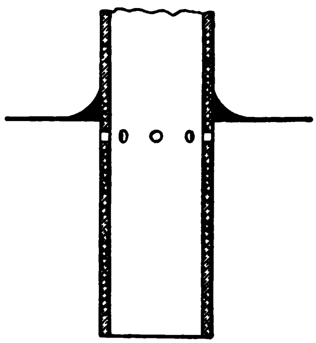


FIG. 10

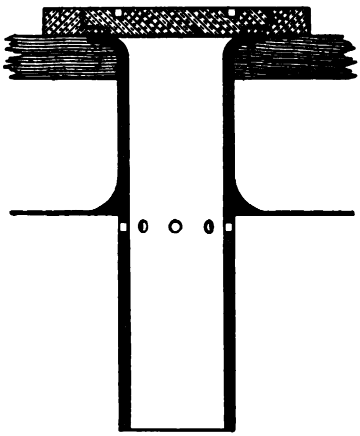


FIG. 11

below these holes, air from the top of the tank displaced by gasoline running in will escape through these small holes and will not cause the gasoline to slop over. The filling pipe may be made of lead and flanged over at the top, as in Fig. 11, the whole being covered by a brass deck plate, or cover, with screw plug.

23. The vent at the highest point of the tank should be a piece of brass pipe extending into the tank several inches and having two small holes as in the filling pipe. To this pipe there should be screwed a brass **T** having at one end a short nipple and check-valve to relieve pressure in the tank, and at the other end another short nipple and check-valve to relieve the partial vacuum in the tank caused by drawing out the gasoline. This arrangement will be found more satisfactory than drilling a pinhole in the plug, or using a loosely fitting screw to relieve pressure or vacuum. Under no circumstances should pressure be applied to the tank to cause gasoline to run to the carbureter.

24. It is sometimes convenient to use copper or galvanized-iron kitchen boilers instead of rectangular tanks. Unless they are especially made and have partitions in them, such boilers should be as short as possible. If they have no partitions, they should preferably be set on end. If they have to be placed in a horizonal position, they should be solidly and carefully blocked and secured, to prevent them from moving and breaking the gasoline-supply connections or piping.

When large quantities of gasoline are to be carried, the tanks should be built like steel steam boilers, with the necessary swash plates riveted and calked, and as a further precaution they should if possible be galvanized inside and out. Cylindrical tanks are preferable to rectangular tanks, and should be employed where there is sufficient room.

In case it should be necessary to locate the tank on deck, the inside of the wooden covering, or hatch, should be lined with asbestos or some other non-conductor of heat. In any case, the same system of drip pan, vents, etc. should be employed, except that for filling purposes a removable hatch may be used if desired, but care should be exercised in filling the tank not to allow it to run over.

25. If the engine is to be operated from some part of the boat other than at the engine, the various controlling devices should be attached and tested to see that they work properly. From whatever point the engine may be handled, a connection must be made so that the gasoline supply may be shut off every time the engine is stopped.

MARINE-ENGINE OPERATION

STARTING, RUNNING, AND STOPPING

26. When an engine is about to be started it is not safe to assume that all the adjustments are correct, just as they were when the engine left the shop, and only by careful examination can the operator be sure that the engine is ready for use. The following general rules may be applied whether the engine is of the two-cycle or the four-cycle type, either single cylinder or multicylinder.

First, determine which way the engine runs normally, whether right-handed or left-handed. When facing the flywheel and looking toward the stern of the boat, if the direction of rotation of the flywheel when the boat is going ahead is

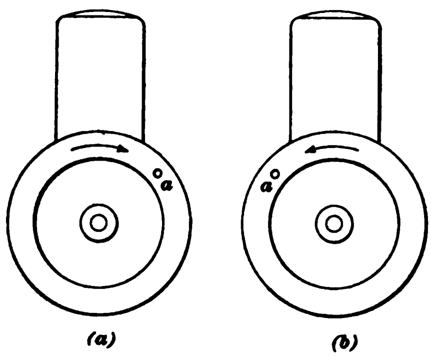


FIG. 12

the same as that of the hands of a watch, as shown by the arrow in Fig. 12 (*a*), the engine is a right-hand engine and requires a left-hand propeller wheel to drive the boat ahead. When the movement of the flywheel is contrary to the direction of movement of the watch hands, as in Fig. 12 (*b*), the engine is a left-hand engine and requires a right-hand

propeller wheel in order to propel the boat ahead. When turning it over rotate the flywheel in its proper direction with the cocks open, or with the compression otherwise relieved. Determine when the piston is on the upper dead center, and make a mark on the flywheel in case the starting pin that fits into the hole *a*, Fig. 12 (*a*) and (*b*), is not where the mark would come. If there is no starting pin, or if it should be set at a point 90° from the upper dead center, mark the flywheel plainly to indicate when the piston is on the upper center, another mark being made on the opposite side of flywheel to show when the piston is exactly on the lower center. If the starting pin in the flywheel is set 90° from the upper center, its position should be changed to correspond with the mark made to show when the piston is on the upper center. Any other location for the starting pin is dangerous, giving rise to broken and sprained thumbs, wrists, and arms, besides other injuries.

Having marked the flywheel to show the position of the piston in the cylinder, then, with the gasoline turned off and the battery switch closed, turn the flywheel slowly until, if a jump spark is used, the spark coil begins to buzz, whereupon another mark should be made on the flywheel. If the make-and-break system of ignition is employed, note where contact is made and where it is broken when the spark occurs. If the engine is of a multicylinder type, try each cylinder separately, to determine whether or not the contact is made at the same relative position for all cylinders and that the spark occurs at the same point before or after the center is passed.

27. If the engine is of the two-cycle type using jump-spark ignition or the usual form of make-and-break ignition, which will allow it to run in either direction, turn the flywheel in the opposite direction until the mark shows it to be about 30° before the upper center. Then, advance or retard the spark until a contact is made just at that point, and note the position of the spark-control lever. If the engine is of the single-cylinder, two-cycle type, the easiest method of starting the

engine is to prime the combustion chamber by injecting a few drops of gasoline into the priming cup with a squirt can, and turn on the gasoline supply in case a carbureter is used, priming it also by depressing the float; if, however, a vaporizer is used, set the needle valve at the point usually made on the dial when the engine is tested, swing the flywheel several times slowly back and forth through a space equal to about one-third the circumference, and then, taking firm hold of the starting pin, swing it up smartly against the compression in a direction opposite to its normal rotation, and then let go. If the engine does not start after trying this two or three times, first close the valve in the gasoline supply, open the relief cock, and turn the engine over three or four times, and note whether or not explosions occur. The relief cocks should be open and the spark lever set so that ignition will occur either just after the center is passed or as near the end of the up stroke as possible.

28. In two-cycle engines using make-and-break ignition that will run in either direction, motion is given to the igniter or movable electrode by means of an eccentric securely fastened to the crank-shaft or hub of the flywheel. The high part of the eccentric is either in line with the crank-pin or directly opposite, usually the former. Reference to Fig. 13 will make it clear that the eccentric carries the rod that moves the igniter upwards during one-half of the revolution of the crank-shaft and downwards during the other half. The tripper must therefore act before the extreme top or bottom center is reached, no matter in which direction the crank-shaft turns. In engines designed to run in but one direction, this is a comparatively simple matter, for the eccentric can be secured so that it will not arrive at its highest point until after the upper center is passed. This is true also of nearly all four-cycle engines; for, unless they are designed to run both ways, the action of the ignition cam

FIG. 13

is retarded, and if designed to run both ways, separate cams for ignition, as well as valve operation, are always employed.

29. Fig. 14 shows a method of arriving at a solution of the problem of igniting the charge before or after the upper center is passed. An eccentric that is not keyed to the shaft

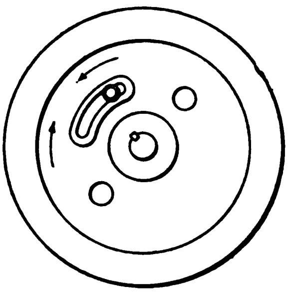


FIG. 14

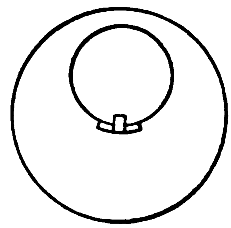


FIG. 15

is provided with a pin that projects through a curved slot in the web of the flywheel; and, by fastening the pin to one side or the other of the middle of the slot, the ignition will be delayed or advanced when the engine is running in either of the directions indicated by the arrows just above the slot.

Another method employed is to have in the eccentric a slot wider than the key that fastens the flywheel, the key extending into the keyway in the eccentric, as shown in Fig. 15, the eccentric being mounted loosely on the flywheel shaft, as in Fig. 14.

30. Fig. 16 shows a double motion used by another manufacturer to obtain the same result. In this figure, *a* is the crank-shaft; *b*, the eccentric; *c*, the eccentric rod, or strap, pivoted at *d* in the slot *g*. The position shown would not allow the pin *f*, which is raised by the forked end of the eccentric rod *c*, to trip and separate the electrodes until a considerable time after the center had been passed; but, if the eccentric *b* were turning in the direction indicated by the arrow, and the eccentric rod *c* were held to the left, it

would trip earlier, or at such a time in the upward motion as desired, this time being regulated by the amount the rod is held to the left, which is controlled by means of the hand lever *h*. If the reverse motion is given to the eccentric, the eccentric rod would give the same time of ignition, provided it were held at the same relative position to the right, instead of to the left.

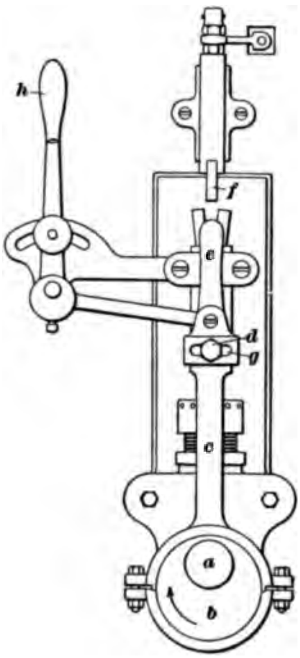


FIG. 16

31. Multicylinder two-cycle engines, unless they have some such means as described for retarding the spark, if designed to run in both directions, are extremely dangerous to start and very much more so if they are provided with a starting pin in the flywheel. Every owner of a multicylinder marine engine should remove the starting pin, if one is used, just as soon as possible; if left in, it may cause serious injury.

A multicylinder two-cycle engine should never be started in the same manner as is usual with single-cylinder two-cycle engines, nor should the attempt to do so ever be made. It is very important that this should be remembered; if any one should attempt to start a multi-cylinder two-cycle engine by rocking the flywheel back and forth, as is customary with single-cylinder two-cycle engines, and there happened to be a charge of gas left in any of the cylinders, the ignition of such charge might cause a serious accident, many persons having been injured in this manner.

32. In four-cycle engines, the use of a starting pin is unnecessary and even more dangerous than with two-cycle engines, for the result would be just as bad if an explosion

should take place and the engine were to start ahead as it would if a back kick occurred and the operator did not let go of the starting pin in time. . Starting pins are unnecessary, engines without them being provided with flywheels of larger diameter so as to be more easily grasped by the operator.

Small sizes of four-cycle engines with flywheels on the forward end of the crank-shafts are usually started by grasping the flywheel, although some are designed to use a starting crank that automatically releases as soon as the engine starts.

33. If a starting crank is used, it is manifestly easier to start a marine engine that runs right-handed than one that runs left-handed. For this reason, nearly all marine engines that are crank-started, are right-handed. The starting crank usually hooks over a pin in the end of the crank-shaft, as in Fig. 17, or over the end of the key holding the flywheel in place, in which case a left-handed crank should be used to run the engine left-handed, or a right-handed crank to run it right-handed.

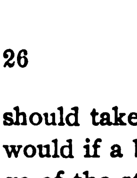


FIG. 17

The pin should so engage the starting crank that the engine will pass the upper center at a point about 45° before the starting crank reaches the center, as in Fig. 18. In this case, to start an engine left-handed on the compression stroke, the crank-handle would describe one-half a circumference, *b-a-d*, or 180°; while, if right-handed, it would be *a-b-c*. The movement of the crank-handle should always be upwards, the object being to lift up on the handle when the greatest force is necessary to compress the charge, and when once begun it is dangerous not to complete the half-turn movement if make-and-break ignition is employed. Supposing the crank to have been advanced to a point *f*, Fig. 18

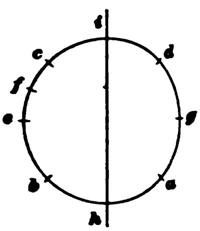


FIG. 18

and that at this point the electrodes were in contact, if the force exerted to compress the charge were removed, the handle might go back to, say, *e*, when, if the electrodes were to separate, a spark would occur and a back kick would result. On the other hand, if the crank were to be carried to *c*, or were to pass it, the piston being thereby carried beyond the upper dead center, the expansion of the compressed charge would carry the piston part way down until the igniter would trip and ignite the charge, and motion would be given to the crank-shaft in the proper direction. Sometimes the crank-handle describes the half circle *g–h–e*, or *e–h–g*, but it is better and safer when the path of travel is *a–b–c* or *b–a–d*. No matter where the crank-handle path is located, if for any reason the operator is unable to get the piston past the upper center, and make-and-break ignition is used, there is danger of back kicks.

34. Instead of a pin through the shaft, a ratchet wheel of one, two, four, or more teeth is sometimes keyed to the shaft. A single tooth is much safer than two or four teeth, more than two teeth being unnecessary as well as unsafe. If a two-toothed ratchet is used, the crank-handle should describe the arcs *a–b–c* or *b–a–d*, also *c–d–a* or *d–c–b*.

In three-cylinder engines having cranks set 120° apart, a three-toothed ratchet should be employed. If a pin is used in the crank-shaft, it should not extend through, as in Fig. 17, but in the starting crank there should be three hooks 120° apart, to give the same relative motion in compressing and exploding the charge in each cylinder.

Where the engine is too large to start by ordinary means, various mechanical devices are employed. Some of them are more dangerous than others, and any one of them in the hands of an inexperienced person may cause injury to the operator or others.

35. Fig. 19 shows one method of using a starting bar. The flywheel for a single-, double-, or four-cylinder engine usually has four cored apertures, arranged 90° apart, with

a and *b* usually 45° ahead and back of the upper center, respectively, and with *c* and *d* diametrically opposite *a* and *b*. There are two rows of these if the engine is designed to be run in both directions. In right-handed

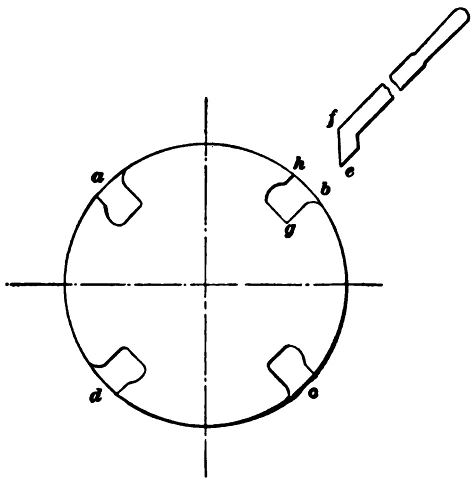


FIG. 19

action, the lever has a toe *e* that comes against the side *g*, with the heel *f* against *h*. As soon as the engine starts, the lever is easily withdrawn; this is, perhaps, the simplest starting-bar system.

Another starting bar, the construction of which is shown in Fig. 20, consists of a toothed ratchet *a*, with a yoked bar *b*, and a pawl *c* engaging the teeth of the ratchet. The teeth are usually hooked more or less, and if the engine is to be run in both directions, it is necessary to have two ratchets and one pawl, turning the forked lever half way around to run in the opposite direction. In this case, as in using starting cranks, it is necessary to see that the explosion does not take place too early, or it may result in injury to the arm.

36. Frequently, in using a crank in close quarters, it is customary to bend it just above the pawl, so that the handle

will lead to a point about 45° from the crankpin. This will make it possible to get a hold lower down. If there are more than four teeth the same danger exists as in the case of more than two teeth to the starting crank. If the engine is not too large to start without relieving the compression, the utmost care should be exercised in starting the engine, and the use of a four-toothed ratchet should be discouraged.

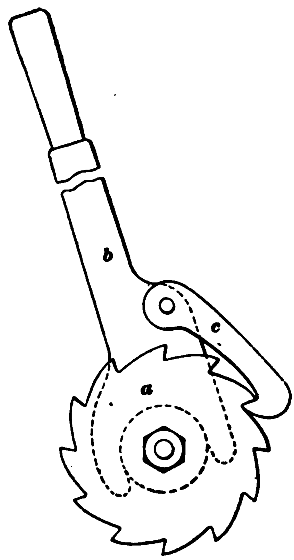


FIG. 20

37. If the engine is one in which the compression must be relieved in order to start, almost any one with a little ingenuity can arrange an attachment whereby the compression may be relieved and the spark retarded at the same time. Fig. 21 shows how this may be done; a, a', and a'' are three cylinders having relief cocks b, b', and b'' connected through a suitable rod to a bell-crank lever c pivoted at d. In the position shown, the relief cocks are open. Suppose, now, that they are in closed position,

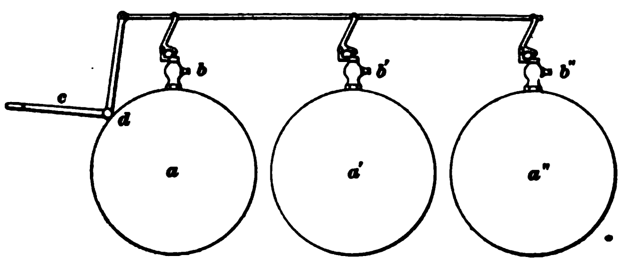


FIG. 21

as indicated in Fig. 22, and that a rod e, passing through a pivoted stud in the spark lever, is provided with collars f and g held in place by setscrews or other means, the rod e

sliding through the guide *i* until the relief cocks are open, or nearly so, before the collar *g* moves to a point where the spark lever indicates that the ignition is in late position. As

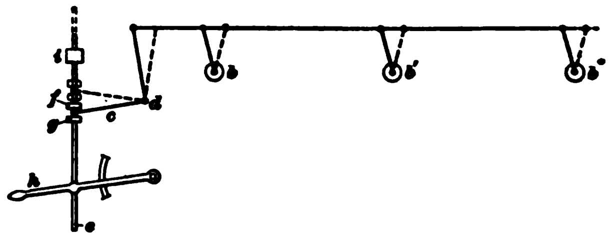


FIG. 22

the engine starts, the *e* rod can be drawn back until the collar *f* engages the spark lever and advances the spark as the compression relief cocks are closed.

In the case of a four-cycle engine having a cam-shaft with an endwise movement to bring a double-lipped exhaust cam into operation to relieve the compression, the same shaft can also bring into operation another cam to control the ignition. There are many ways to accomplish this object, and, on account of securing greater ease of operation, it is suggested that all owners of gasoline marine engines should study out some way to make a connection between the compression relief and spark control.

38. One means of relieving the compression, used only in four-cycle engines, consists in having the exhaust valve open during a part of each compression stroke; while another consists in using cylinder relief cocks screwed into openings either through the cylinder walls and covered by the piston when near the end of the up-stroke, or into openings communicating directly with the combustion space above the top of the piston. Compression cocks are necessarily employed in two-cycle engines, and because of their cheapness they are finding favor among manufacturers of four-cycle engines. There is, however, an element of danger associated with their use, as many boats that have

been burned would not have taken fire except through relief cocks. When used in cabin boats, the relief cocks should be piped outboard or into the exhaust, for, if there should be present in the boat's cabin or under the floor gasoline vapor and air in the proportions of an explosive mixture, with the relief cock open and shooting a column of flame down toward this mixture, an explosion might result that would destroy the boat. If compression relief cocks are used, they should, therefore, always point upwards instead of downwards. Combined relief and priming cocks can often be used for priming the cylinders, but separate priming cups should always be used where the engine is installed in a cabin.

39. Starting an engine having no reversing gear, but with a reversing propeller, is somewhat easier than to start with a propeller connected rigidly to the propeller shaft, the feathered blades of a reversing propeller acting to relieve the engine of nearly its full load, while a solid propeller and shaft carry a full load. In the latter case, no governor is required. In order to run the boat astern with an ordinary two-cycle engine, the engine is stopped and run in the opposite direction. As this is impractical with four-cycle engines, governors are quite necessary in all reversing-gear engines of more than 6 or 8 horsepower, although some makers do not use them at all, or not until the engine reaches from 16 to 20 horsepower. In case no governor is used, great care should be exercised to prevent the engine from running away. As governors sometimes fail to act, it is always better, when starting an engine, to have the throttle within easy reach, as well as the switch, in order to prevent an accident. If the engine has an auxiliary air supply, as many four-cycle engines do, it is usually closed on attempting to start, as it is better to have the mixture a little too rich than a little too poor in gasoline vapor.

40. Before starting a four-cycle engine, the operator should be satisfied that the inlet and exhaust valves, as also the spark, are correctly timed, that the adjustments are

correct, that the valves all seat properly, and that they are not rusted or stuck in their guides. A drop or two of kerosene oil should be used occasionally on the valve stems. Be sure that all the oil cups are filled, that all moving parts are properly lubricated, that the sea cock is open, and that there is nothing to prevent the free passage of water through the cylinder water-jackets and thence outboard. Look out for ropes that may be wound up by the propeller; a few accidents from this cause will usually teach caution as nothing else will. Make sure that the electric-ignition system is in good working order by testing it with the current on, if of the make-and-break type, or by the buzzing at the spark coil if jump-spark ignition is used. Next open the relief cocks or push the relief cams into position, turn on the gasoline and see that it runs freely, and turn the engine over two or three times as fast as convenient. To facilitate starting, it is sometimes better to put a little gasoline into each cylinder through the priming cocks. This operation is called *priming*. After two or three revolutions, the engine should start, when the relief cocks should be closed or the relief cams thrown out, and the speed of the engine regulated by the throttle, the proportions of the mixture being regulated by the auxiliary air valve or by the needle in the gasoline valve, unless a compensating or other form of carbureter is used. If the engine misses explosions, it may be that it is throttled too much, but it is more probable that the mixture is too rich in gasoline vapor. If the engine begins to slow down, give it a little more gasoline, and if that does not remedy matters decrease the amount, or increase or decrease the amount of auxiliary air. When the engine is running satisfactorily, open the oil cups and see that they feed properly and that the jump operates, watching, of course, for overheated bearings, as in any new piece of machinery.

41. If the engine is directly connected to the propeller, there is nothing else to be done except to get the proportions of air and gasoline vapor as nearly right as possible,

see that lubrication is constant, and that the circulating water discharges freely. If the engine has a reversing gear, there will be little need of throttling when changing from full speed ahead to a neutral position or full speed astern; but with a reversing gear and no governor, extreme care should be exercised in throwing in either gear or the engine may be stopped. The reversing gear absorbs some part of the power of the engine, which is more liable to stop when attempting to go astern than ahead. It will be necessary, in case a governor is not used, to have some practice in order to be sure that the engine will not be stopped when throwing in the gears, and in order to be able to handle the throttle properly. With a governor, however, the manipulation of the engine is largely a question of properly proportioning the mixture of air and gasoline vapor and of proper adjustment.

42. Once started and running, the engine may not turn up to its usual speed, may miss explosions, or may seem to labor hard. In such cases, an examination should be made to see that the lubrication is sufficient and regular, remembering that a little too much lubrication is not so bad as too little, although an excess of oil in the cylinder may give trouble later. As the effect of too much oil is indicated by the color of the exhaust, trouble from this source is easily discovered and can easily be remedied.

An attempt should first be made to remedy the trouble, if possible, by varying the proportions of the mixture of air and gasoline vapor. Then, the electrical connections should be examined carefully to see if they are tight. If conditions seem to get worse instead of better, it will be necessary to stop the engine and search out the trouble, for it would be imprudent and possibly dangerous to continue running.

43. When the engine is to be stopped, first throw in the compression relief cam or open the relief cocks. The object of relieving the compression is to prevent the engine from running after the electric current is thrown off, the mixture remaining in the cylinders igniting from incandescent

particles of carbon attached to the piston or walls of the cylinder. The switch should then be thrown out and the oil cups shut off. When using reversing gears, it is always better to stop in the neutral position, neither going ahead nor astern, for it is usually much easier to release a clutch when the engine is running than after it has been stopped. The gasoline-supply valve, which should always be placed in the supply pipe directly back of the vaporizer or carbureter, should then be closed.

Among several reasons for adopting this method of procedure when stopping an engine the following may be mentioned: If the engine is stopped by entirely closing the throttle, its closed position may not be noticed when attempting to start, and with the throttle closed the cylinder will be filled with a charge of burned gas instead of a fresh charge of explosive mixture; the engine should not be stopped with the switch on and the make-and-break electrodes in contact, as the batteries would thus soon be exhausted.

Shutting off the gasoline at the vaporizer by means of the needle valve is extremely bad practice. It is much better and more satisfactory to close the valve or cock in the supply pipe, for should a leak develop at the union in the piping to the carbureter the closing of the needle valve would not prevent gasoline from leaking into the lower part of the boat. Shutting off the supply at the vaporizer in two-cycle engines is more likely to cause crank-case explosions or back fires than in four-cycle engines. Back firing is caused by a too weak mixture of vapor and air, which is slow-burning. In four-cycle engines, more time elapses between the opening of the exhaust and the inlet valves than in two-cycle engines, in which the inlet port is opened almost at the same time as the exhaust. The faster the two-cycle engine runs, the less time there is between the opening of the two ports and the greater the liability to crank-case explosions or back firing.

44. In shutting down an engine, some operators are always careful to close the sea cock. This is unnecessary

and is liable to cause more harm than good; for, were the engine to be started with the sea cock closed, considerable damage to the engine might be caused by overheating. Rubber hose should not be used for the connection from the pump to the sea cock, and if suitable piping is here used there is little if any danger from a leak developing while the engine is not running.

As a precautionary measure, it is always good practice to close the gasoline valve at the tank at the same time it is closed at the vaporizer or carbureter.

CARE AND REPAIR OF ENGINE

CARE OF ENGINE

45. The proper care of an engine and its auxiliaries depends largely on the character of the engine. When an engine is exposed to the action of salt water that frequently comes aboard as spray, it requires more care than when installed under cover. While the exterior of an engine should always be kept clean, this is not so essential as that all bearings and moving parts be kept free from rust, gummed oil, and dirt, and that the lubricating system may be depended on when the engine is running. Loose bearings should be remedied promptly, all bolts and nuts should be examined frequently, replaced if lost, tightened if loose, and where holes are drilled in the ends for spring cotters, the latter, if not in place, should be replaced. To avoid possible trouble with the gasoline supply and carburization, gasoline tanks and piping should be inspected occasionally for accumulations of water and dirt. The carbureter or vaporizer should be looked after, and the lubricator sight-feed glasses, if clouded so that the feed cannot be seen plainly, should be cleaned with kerosene or gasoline.

Salt water injures machinery, and should by all means be kept from the reversing gear or clutch; for, in addition to its oxidizing effect, the presence of dissimilar metals in the

salt water gives rise to electrolysis, which is very destructive to studs, bolts, gears, shafts, etc.

In cold weather, the water should be carefully drained from the water-jacket, pump, and piping, to prevent it from freezing and thus bursting the water-jacket. While burst piping can readily be replaced, it is not an easy matter, even when possible, to repair a broken water-jacket, or even to replace a pump.

Lubrication of the reverse gearing, clutches, and thrust or spring bearings should not be forgotten. The stern bearing is lubricated by the water, while stuffingboxes are lubricated by the flax packing, which is usually filled with tallow or some similar substance.

Kerosene will be found very convenient to use in loosening gummed oil on bearings and even in the cylinder it may be used freely to loosen up accumulations of carbon and burned oil. In fact, kerosene is a necessity for occasional use on valve stems in four-stroke engines or on the movable igniter bearings in engines using make-and-break ignition. A little vaseline or cylinder oil may be used to coat bright parts to prevent them from tarnishing, but the former is much cleaner than the latter. Special care should be exercised to see that sufficient supplies are always on board—plenty of gasoline, oil, tools, a good reserve battery, always a pail to use in case of fire or a bad leak, a dry-powder fire-extinguisher to put out possible gasoline fire, and a life preserver for each person on board, for personal safety is of the greatest importance.

LAYING UP THE ENGINE

46. In leaving the engine after a run, the gasoline should always be shut off at the tank, and also at the valve near the carbureter or vaporizer. The lubricators should be closed, and any excess of oil on the engine wiped off while the engine is warm. If cold weather is threatened, drain the water-jacket, pump, and piping, and cover the engine with canvas, being careful that it does

not touch an over-heated exhaust pipe, where it is liable to take fire.

When the season is over, and the boat is ready to lay up for the winter or the closed season, the engine should be taken out of the boat if convenient. If not it should be cleaned carefully and the bright parts covered with vaseline, white lead and tallow, or something that will protect the parts and still be easily removable. Plenty of cylinder oil should be left in the cylinder, the flywheel should be turned over two or three times, the piston being left on the outer center to prevent any possible rusting of the upper surface of the cylinder, where it is quite important that there should be a smooth surface. A multiple-cylinder engine should be turned over occasionally to guard against similar trouble. If the engine is to be left in the boat, it should be protected with a water-tight covering, no part of which should be allowed to touch the engine, as such contact is very sure to cause rusting.

If these precautions are carefully observed, very little trouble should be experienced in putting the engine in commission at the beginning of the season. It may be well to remove a large part of the oil put in when the boat was laid up; the engine should then be as easy to start as when put away.

TOOLS AND REPAIR PARTS

47. A few tools are always necessary in running a marine gas engine to get at or remove parts that may have to be taken down for adjustment, repair, or inspection. A pipe wrench is indispensable, also a good-sized adjustable monkey wrench (say about a 14-inch), a small and a large screwdriver, pair of adjustable hawk-bill plyers, bicycle wrench, three-cornered and half-round second-cut or bastard files, 8 and 10 inches long, respectively, light round peen hammer, $\frac{1}{4}$-inch cape chisel, two or three cold chisels of different lengths, a center punch, a small round nail set, and such other small tools as may be useful in case of emergency. The tools liable to rust can be carried conveniently in a

waterproofed canvas roll, where they may be found when they are required; but the pliers, on account of their frequent use, might better be carried in the pocket. One of the most convenient tools on board a boat is a small hand vise, similar to those used by electric linemen. It will hold almost anything it may be desired to file, and while not absolutely necessary will often be found a convenience.

Tools are of little use unless there is at hand an assortment of supplies, including shellac, strong cotton cloth, insulated wire, soft copper wire, hard bronze spring wire of different sizes, insulating tape, some strong cord, small pieces of canvas, some soft sheet brass or copper .003 or .005 inch thick, and, if possible, a roll of gasket material in a water-tight tin box to prevent it from becoming wet or broken. An assortment of nuts, cotter pins, etc., as well as duplicate small parts liable to become broken, such as igniter springs, could be carried in a spice box to obviate a serious breakdown.

MANAGEMENT OF STATIONARY GAS ENGINES

INSTALLATION

SELECTION OF ENGINE

POINTS GOVERNING SELECTION

1. In selecting a stationary gas engine there are several important points to be considered, and the engine that embodies the greatest number of desirable qualities is the one to be preferred. First of all, the engine must possess sufficient capacity to accomplish the desired work. It must also be adapted to the requirements of speed, regulation, and direction of running imposed by the work to be done. It should be economical in fuel consumption, reliable in service, and of simple construction.

2. In determining the size of an engine for a given amount of work, it should be borne in mind that an engine that is called upon to run at its full capacity during the greater part of the time is actually overtaxed. Working an engine to this extent will result in rapid wearing of the cylinder and piston, and consequent loss of power and economy due to leakage. When doing the maximum amount of work possible in a plant, the engine, if governed by the regulation of the number of impulses, should cut off at least once in four or five charging strokes. This will benefit the cylinder through the admission of charges of pure cool air at more or less regular intervals.

3. The type of engine decided on should be the one most suitable for the work it is to do. Engines for operating electric generators, especially for lighting purposes, must run with greater steadiness than is generally required for ordinary power. There are other cases—such as the operation of sensitive typesetting machines—where a very steady speed is desirable. The question whether a horizontal or a vertical engine should be selected must be settled with a view to local conditions of available space and the character of the work to be done.

4. The consumption of fuel should always be in proportion to the work performed by the engine. The governor should respond promptly to any fluctuation in the load, and the friction loss should be kept at a minimum by proper methods of lubrication. The attainment of good results depends largely on careful workmanship, as well as on properly proportioned valves and liberal bearing surfaces.

5. The engine should be capable of being started promptly without great exertion, of developing its rated horsepower, and maintaining a steady speed, while consuming the normal amount of fuel.

6. Other things being equal, the engine that is simplest in construction and operation is to be preferred. This, however, should not be carried to a point where reliability of running and accessibility of the working parts are sacrificed. All the working parts, such as piston, connecting-rod, valve gear, igniter, etc., should be in plain view and easy of access for cleaning and necessary repairs.

EXAMINATION OF ENGINE

7. Even a casual inspection will reveal to the eye of a mechanic certain evidences of good or bad workmanship. Among the points that should be observed are the condition of the threads and the fitting of the nuts and their wrenches. Threads should be full and smooth, and the

nuts should fit so as to enable them to be turned by hand on the studs or bolts, although they should fit snugly—that is, without play. The jaws of the wrenches should fit the nuts exactly. The fit of pins, levers, or links can be inspected by moving them by hand, when they should slide smoothly and evenly. Whenever possible, moving parts subject to wear should be properly hardened to a moderate depth below the outer surface. This refers especially to cams, rollers, blades, and pivot pins.

8. When in motion, the good workmanship of an engine is indicated by smooth and noiseless running. There should be no pounding or clattering sound, which would indicate lost motion and loose-fitting bearings or piston. The flywheels should run true and without vibration. If the rim of the wheel should show any vibrating motion at the time of the explosion, it would be evidence of weakness either in the crank-shaft or in the wheel itself. The proper balance of the revolving and reciprocating parts is indicated by the absence of any forward and backward sliding of the engine bed on its base or foundation.

9. When the engine is operated with illuminating gas, the consumption of fuel is best determined by reading the meter at the beginning and at the end of a certain period of time while the engine is running under its rated load. As a rule, manufacturers guarantee the power and the gas consumption per brake horsepower under full and partial loads. A gasoline engine should be tested as to its fuel consumption by connecting the pump to a graduated bottle of about 1 gallon capacity, and the amount used for a certain period should be noted. A good engine, running with ordinary stove gasoline, should use about a pint of fuel per brake horsepower per hour when running under its rated load.

10. Before deciding on the make and type of engine contemplated for a certain purpose, it will always pay to investigate the working of engines of the same manufacture that have been in use for a reasonable length of

time. Reports from reliable users will go far towards determining the actual merits of an engine, its economy, the amount of repairs it may be expected to require, and other matters of vital interest to the power user.

ERECTING THE ENGINE

LOCATION OF ENGINE

11. The selection of the most suitable location for an engine deserves careful consideration. The space to be occupied by the engine should, if at all possible, be separated from the rest of the room by a partition. Sufficient space should be allowed around the engine, especially on the valve and governor side, where the space should be not less than 3 feet, to permit of easy access to any part of the engine. In all factories or shops where the presence of flying dust is unavoidable, it is necessary that the engine room should be surrounded with dust-proof walls. A room well lighted and ventilated is a great help in keeping the engine in proper condition, since it allows the attendant to watch closely the lubrication, valve motion, action of the governor, etc. The use of an open belt is always preferable to a crossed belt running from the engine to the line shaft. The engine should be set in relation to the direction in which the shafting or machines to be driven will revolve, and the question of open or crossed belt should be decided with this point in view. The distance between the centers of the engine shaft and the line shaft or the machine to be operated should never be less than 10 feet for engines up to 10 horsepower, and from 12 to 20 feet for engines of larger size.

FOUNDATION

12. Foundation Templet.—The location of the engine having been determined, the foundation may be prepared. Plans and specifications giving the size, depth, and material

of the foundation are usually supplied by the builders of the engine, and in many cases a templet is also provided by them. This templet is a rigid framework, made of 1- or $1\frac{1}{4}$-inch boards from 4 to 6 inches wide, in which holes are bored corresponding to the holes in the engine bed through which the **holding-down,** or **foundation, bolts** must pass. If the templet is not provided by the maker of the engine, it should be constructed in accordance with the dimensions given on the foundation drawing. If the engine bed is at hand, it is well to measure the distances between bolt holes, and compare these distances with those shown on the drawing. If they do not agree, as is sometimes the case, the holes in the templet should be located by measurements taken from the engine bed. The engine builders often furnish the foundation bolts, nuts, washers, and anchor plates.

The center lines of the cylinder and crank-shaft should be marked on the templet with a scriber. In setting the templet, care should be exercised to have it the required height from the floor, level on top, and square with the building. This is done because the templet is used to determine the height of the top of the foundation bolts as well as their position laterally. If the shafting to be driven is in place, the center line of the crank-shaft as marked on the templet must be brought parallel with that of the line shaft. To accomplish this, drop two strings with weights attached, one on each side of the foundation and several feet away from it, from the line shaft to the floor. Then set the templet so that a string drawn across it, and exactly in line with the center line of the crank-shaft, is the same distance away from the two plumb-lines suspended from the line shaft. The crank-shaft will then be parallel with the line shaft, so that they may be connected by pulleys and belt.

13. Placing Foundation Bolts.—After the templet has been set and securely propped up and fixed in position, the foundation bolts should be inserted, allowing the top ends to extend the proper distance above the bottom of the templet. When the nuts and washers are in place, so that the ends of

bolts project slightly beyond the nuts, the distance above the bottom of the templet should be adjusted so that it will equal the distance that the bolts should project above the top of the foundation.

In order to guard against any slight shifting of the foundation bolts while the masonry is being put in place, or against discrepancies between the foundation plan and the engine bed, it is advisable to surround the bolts with wooden casings or, preferably, with iron pipes about 1 inch larger on the inside than the diameter of the bolts. This will permit the bolts to be moved slightly in the foundation and their location to be adjusted to suit the actual measurements of the engine bed.

14. Building the Foundation.—The building of the foundation may now be undertaken. If brick is used, it should be of the hard-burnt quality, and should be laid in mortar made from a good quality of Portland cement and clean, sharp building sand, with a sufficient amount of water to render the mortar of the proper consistency. Common brick or building stone may be used for the inside of the foundation, but the outside should be faced with pressed brick.

In many cases, a foundation of concrete is cheaper or more convenient to construct than one of brick or stone, and, if built of a proper grade of material, is preferable to a brick foundation. A good mixture of concrete may be made of five parts, by volume, of broken stone, about 1½ inches in size, two parts of clean, sharp sand, and one part of Portland cement, adding water in proper quantity and thoroughly mixing the material to give it the required consistency. After the pit has been filled with concrete up to the floor level, build or place a box under the templet, the inside measurements of which should correspond with the size of the part of the foundation that projects above the floor. Fill the box with concrete, and do not remove it until the mixture has become well dried, which generally requires from 3 to 4 days. After the box has been removed, the sides and top of the foundation should be

finished with cement mortar, so as to give it a smooth appearance. The templet should not be removed until the foundation has completely dried, as there is danger of the bolts being drawn out of their proper position during the setting of the foundation.

A properly built concrete foundation becomes as hard as a solid mass of stone. Brick foundations for large engines should, if possible, be topped with a cap of sandstone or similar material. Oil has a deteriorating effect on concrete or brick foundations. In order to protect them against the injurious action of any lubricating oil that may accumulate on top, it is well to provide a sheet-metal oil pan in which to place the engine bed, or to have a 3-inch plank covered with sheet metal to form the top of the foundation for engines of small or medium size.

The depth of the foundation required depends on the nature of the soil, and the pit in which the foundation is to be built should be dug down to solid earth. The distance it is necessary to dig in order to reach solid earth determines the length of the foundation bolts. They should extend to within 6 to 12 inches of the bottom of the pit. The anchor plates, which are attached to the lower ends of the bolts, should be of ample size, so as to prevent any yielding of the foundation material when the bolts are tightened.

15. Preventing Vibration.—To prevent the vibrations caused by the explosions in the engine cylinder from being communicated to the building, the engine foundation should be kept free from contact with the foundation walls of the building. This is of special importance in office buildings, stores, etc. In cases where such vibrations are very objectionable, it is advisable to take the precaution of placing the foundation on a cushion formed by a 6-inch layer of mineral wool, tan bark, or some other insulating material. This should be placed not only beneath, but also all around the sides of the underground portion of the foundation. Cushioning the foundation in this manner not only prevents the transmission of vibration, but also prevents the noise caused

by the running of the engine from being communicated to the rest of the building. A large and heavy foundation also tends to prevent the transmission of vibration, and when the engine is securely bolted to such a foundation most of the vibration of the engine will be absorbed by the foundation.

16. Timber Foundations.—In localities where brick, concrete, or stone foundations are not to be had, timbers may be used. They should be of such length as to project several feet on each side of the engine bed. If several timbers are required to make up the desired height or width of the foundation, they should be bolted together in a substantial manner. The bolts that hold the engine to the timbers should extend through the entire depth of the timbers and be provided with large square heads fitted in countersinks of corresponding size to keep the bolts from turning when the nuts are tightened.

17. Support of Engines on Floors.—Engines of small or medium size are frequently set on upper floors, where a brick or concrete foundation is out of the question. In such cases, the engine is usually provided with a heavy cast-iron base of sufficient height to allow the flywheels to clear the floor; the heavy base absorbs a considerable portion of the vibration, and in a measure takes the place of a foundation. When located on an upper floor, the engine should be set in a corner near the walls, to avoid springing the joists. In every such case, the floor boards should be removed and a thorough inspection of the condition of the joists made, so as to be sure that they are of ample strength to sustain the weight of the engine and absorb the shocks caused by the explosions. Preferably, the engine should be placed so that the length of the bed extends across the joists. In order to take in as many joists as possible, 3-inch planks or heavier timbers projecting several feet on each side of the bed should be placed under it, and held to the joists by bolts extending through and secured by anchor plates underneath. The engine should be fastened to the plank by bolts in the same manner as in the case of the timber foundations.

18. Placing Engine Bed on Foundation.—After the engine bed has been brought alongside the foundation, blocks are placed on top of the masonry high enough to clear the tops of the foundation bolts. The bed is then moved and set upon the blocks and gradually let down by inserting planks and removing the thicker blocks. Generally the bottom of the bed is planed smooth, so that, if the top of the foundation is level and smooth, the bed will rest firmly on the foundation. Any unevenness in the surfaces of the foundation or of the base of the bed must be taken up by wooden or iron wedges, which are inserted and adjusted until a spirit level applied to the engine indicates that it stands perfectly level. After the engine is leveled up, the nuts of the foundation bolts should be tightened gradually and evenly without straining the engine bed. If tightened carelessly, the bearings of the engine in the bed may easily be drawn out of line and cause serious trouble with hot boxes as soon as the engine is started.

19. Grouting.—After the bolts are tightened moderately, the space between the bedplate and the foundation is filled with grouting. The grouting may be made of iron borings mixed with cement, sal ammoniac, sulphur, and water in about the following proportions: two parts of sal ammoniac, one part of sulphur, five parts of cement, and forty parts of iron borings mixed with enough water to make a heavy paste. This mixture rusts firmly into place. A joint made of a rusting mixture is generally called a **rust joint.** Sometimes, melted sulphur alone is used, but one of the best groutings and the most easily applied is pure Portland cement mixed with water. The rust joint must be well tamped into place, while the sulphur and cement will flow in, suitable dams being constructed to hold it in its proper place. Bolt holes should also be filled with liquid grouting. Some builders, who use hollow bedplates of box form, fill the entire bedplate with concrete, to give it solidity and to reduce the tendency to excessive vibration from the knocking caused by loose bearings.

PIPING SYSTEM

20. Arrangement and Sizes of Piping.—It is customary for the engine manufacturer to supply a general piping plan, giving a diagram of the various pipes and their sizes, for the fuel-supply, the water-inlet and overflow, and the

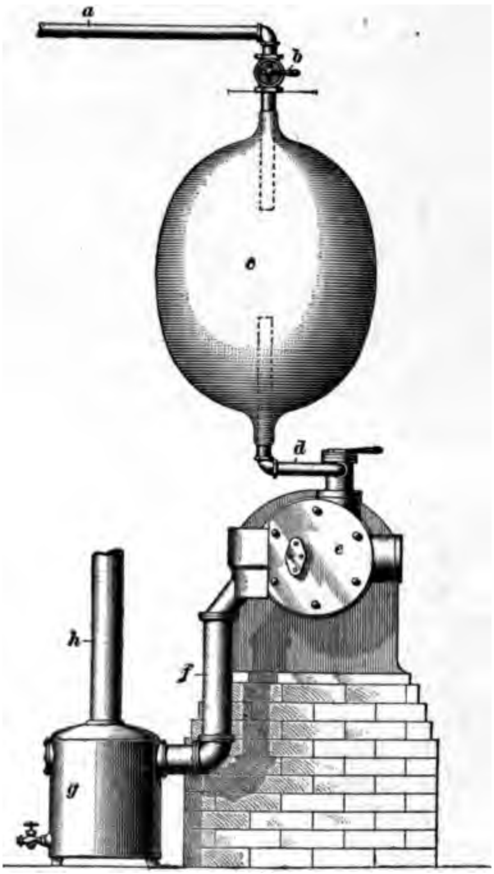


FIG. 1

exhaust pipes. The general scheme of these connections for the gas and exhaust piping, subject to changes according to local circumstances, is shown in Fig. 1. The gas enters through the pipe *a*, and flows through the valve *b* to the gas

bag *c*. From *c*, it passes through the pipe *d* to the engine cylinder *e*. The exhaust gases pass from the cylinder through the pipe *f* to the muffler *g*, and thence out of the pipe *h* to the atmosphere. The gas bag is furnished with the engine, and serves as a reservoir, which is necessary because the charges are taken into the engine suddenly and at intervals. During the suction stroke the gas bag will slightly collapse, and if the pressure should accidentally fall below the normal, the collapsing of the bag may partly close the gas pipe entering it. To guard against this, the pipes should extend well into the bag, that is, from 6 to 12 inches, according to the size. To prevent absolutely such interference with the supply, the pipe may run through the entire length of the bag, the gas entering through a series of holes drilled into the pipe. About twenty holes, varying in size from ¼ to 1 inch in diameter, according to the size of the engine and supply pipe, will be sufficient.

To obtain the full power that the engine is capable of developing when using illuminating gas, the size of the gas-supply pipe must be ample to permit the gas to flow without reduction of pressure, and will depend on the distance between the engine and the street main. Table I gives a safe estimate for the sizes of pipe to be used at different distances from the engine for light pressures of from 1½ to 2 ounces.

TABLE I

SIZES OF GAS PIPING FOR GAS ENGINE

Horsepower of Engine	Diameter of Pipe, in Inches		
	Within 15 Feet of Engine	Further Distance of 90 Feet	Further Connection to Main
2	¾	1	1¼
3 to 5	¾	1¼	1½
6 to 10	1	1½	2
11 to 18	1	2	2½
19 to 28	1¼	2½	3
29 to 45	1½	3	3½
46 to 65	2½	3½	4
66 to 100	3	4	5

21. Pressure Regulator.—In cases where the fluctuations in the gas pressure must be considered, and where the surrounding gas lights would flicker owing to the intermittent drawing of gas from the main during the working of the engine, a **pressure regulator** should be installed. One form of regulator is shown in Fig. 2. It consists of a

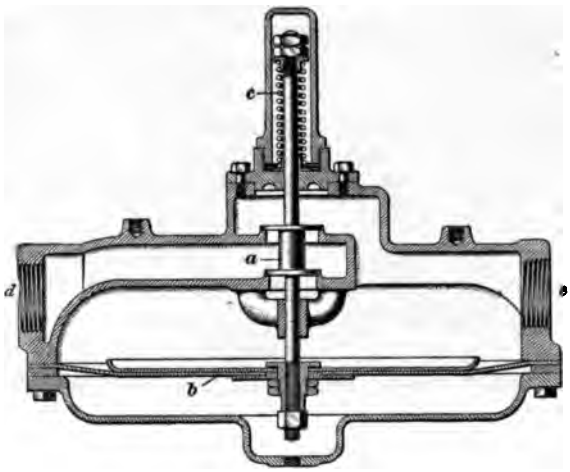


FIG. 2

balanced valve *a*, the stem of which is connected to a diaphragm *b*, and a helical spring *c*, the tension of the latter being adjustable. The gas enters at *d* and leaves at *e*, the diaphragm *b* being therefore subjected to the pressure on the outlet side of the valve. If this pressure increases, the diaphragm is forced downwards, and the valve is closed to a greater or less extent, thus throttling the gas supply and lowering the pressure on the outlet side. By adjusting the spring *c*, any desired pressure may be constantly maintained at *e* regardless of variations in the pressure on the inlet side.

The regulator must be placed in the supply pipe, so that the gas will pass through the valve before it reaches the rubber gas bag *c*, Fig. 1.

A valve shown at *b* should be placed in the supply pipe, so as to shut off the gas before it reaches the bag *c*, and should

be within easy reach, to be opened or closed when starting or stopping the engine. As oil has a damaging effect on rubber, the bag should be inclosed in a suitable box or cover, in order to protect it from lubricating oil that might be thrown upon it by the revolving parts of the engine.

22. Gas Meter.—To permit a strict account of the gas consumption of the engine to be kept, a meter registering the amount of gas used by the engine should be installed. The meter should be placed as near as possible to the engine. The following capacities of meters may be considered ample for engines of various sizes working under normal conditions, the meters being rated according to the number of lights they will supply.

TABLE II

SIZES OF GAS METERS

Horsepower	Size of Meter, in Rated Number of Lights	Horsepower	Size of Meter, in Rated Number of Lights
2	10	26 to 35	80
3 to 5	20	36 to 45	100
6 to 10	30	46 to 55	200
11 to 18	45	56 to 70	250
19 to 25	60	71 to 85	300

23. Piping for Natural Gas.—The pipe connections for natural gas are essentially the same as for illuminating gas. As a rule, natural gas is supplied at a higher pressure, which must be reduced by a suitable regulator to about 2 to 4 ounces before it reaches the reservoir near the engine. Owing to its greater heating value, a smaller amount of natural than of illuminating gas is required for developing the same power, the proportion being about 75 or 80 per cent. The size of the supply pipe near the engine may therefore be proportionately smaller for natural gas than the sizes given in Table I for illuminating gas.

24. Exhaust Piping.—The object of the exhaust pipe is to carry the waste gases or products of combustion into

the open air. To do this effectively and with the least resistance or back pressure, the pipe should be of ample size and should run as straight as possible, avoiding any sharp bends. As the gases leave the cylinder at considerable pressure, the exhaust is noisy unless provision is made for muffling the sound. This is usually accomplished by inserting a cast-iron muffler, as shown at *g*, Fig. 1, in the exhaust pipe near the engine. A flange union should be provided between the exhaust pipe and the engine, and between the exhaust pipe and the muffler, to facilitate the disconnecting of the pipe in case the exhaust valve or the cylinder head needs repairing. In placing the muffler and connecting it to the exhaust outlet of the engine, care should be taken to give the pipe a certain amount of flexibility, as a rigid arrangement would strain the exhaust-valve casing, owing to the expansion of the pipe when it becomes hot. This would result in rendering any packing between the cylinder and exhaust-valve casing leaky, an annoyance that can easily be avoided by a judicious arrangement of the muffler and pipe connections. The most efficient way to avoid this difficulty is to use an expansion joint, one form of which is shown in Fig. 3. The end *a* of the pipe leading from the engine is free to move longitudinally in the fitting *b*, which is screwed tightly on the pipe *c* leading to the muffler. The nut *d*, when screwed down, compresses the packing *e* and prevents leakage between the pipe *a* and the fitting *b*. The expansion joint is thus a simple form of stuffingbox, the packing being of asbestos wick thoroughly lubricated with graphite. Expansion and contraction due to changes of temperature cause the pipe *a* to move in and out of the fitting *b* without straining the pipe connections. The pipe from the muffler to the open air should never be smaller

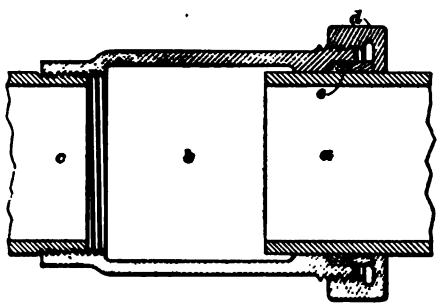


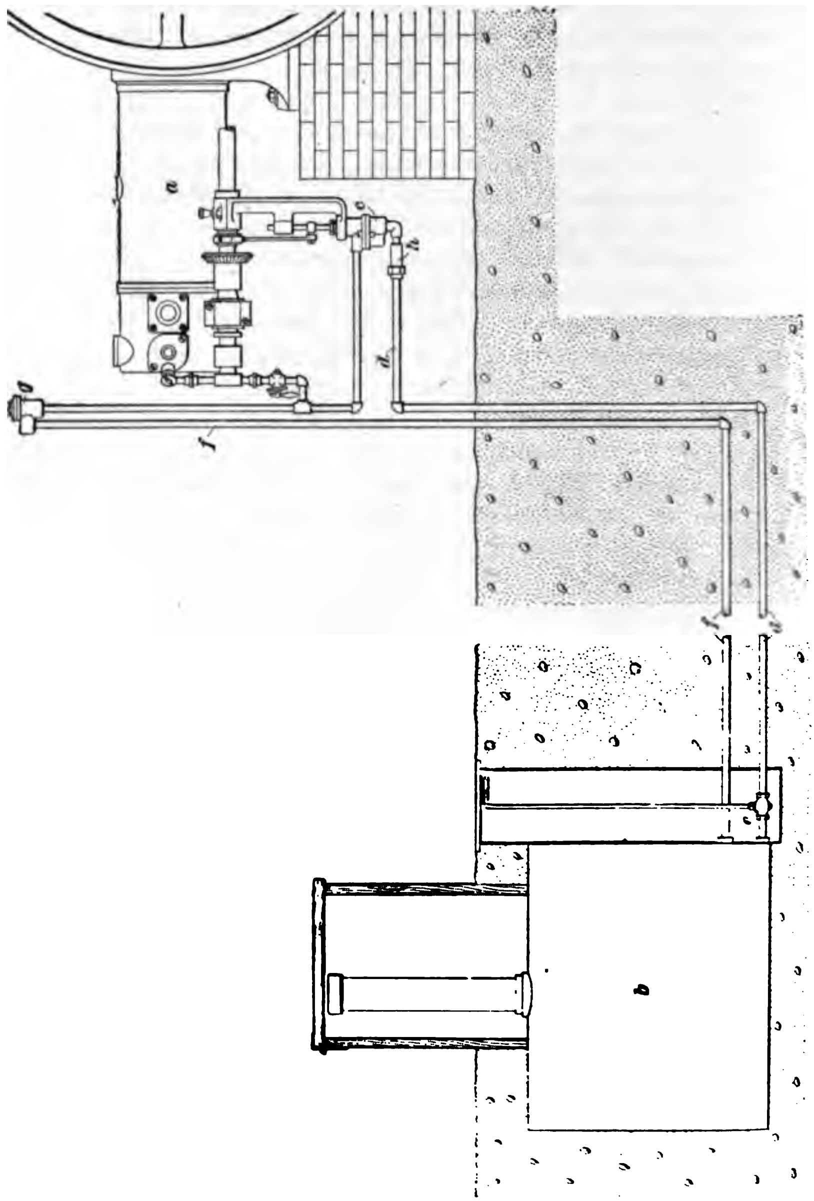
FIG. 3

than the outlet on the engine. If a long pipe with several bends is unavoidable, the size of the pipe should be correspondingly enlarged.

25. To avoid causing annoyance, from the exhaust gas, to people in neighboring buildings, the exhaust pipe should be carried above the roof of the building. If this is done by way of a convenient flue or chimney, the pipe should be carried up through the entire length of the flue. If the pipe terminates inside of the flue, there is danger of unburned gases accumulating in the flue and doing serious damage when fired by the first hot exhaust issuing from the pipe. As the exhaust gases cool during their passage through the pipe, a certain amount of water collects in the pipe due to the condensation of the water vapor in the exhaust gases. To permit the exhaust connections to be drained, all vertical exhaust pipes should be fitted with a **T** at the bottom, one opening of the **T** being provided with a plug or drain cock.

In densely populated or crowded residence districts, where even the muffled sound of the exhaust might become objectionable, the noise can be entirely eliminated by injecting a very small stream of water into the exhaust pipe. A portion of the overflow from the water-jacket may be used for this purpose. The connection should be made about 4 to 6 inches below the exhaust outlet on the engine, to guard against any water coming in contact with the exhaust valve and poppet. A $\frac{1}{8}$-inch pipe will supply enough water to deaden effectually the noise from the exhaust of a 20-horsepower engine. The water has the effect of cooling and decreasing the volume of the hot exhaust gases, and the greater portion of the water is carried away with the gases in the form of steam. A drain connection must be provided at the lowest point of the exhaust pipe, and this must be kept open constantly, to permit any surplus water to run off to the drain pipe or sewer.

In running the exhaust pipe through wooden floors or partitions, metal plates should be used around the pipe,



allowing 3 or 4 inches clearance between the pipe and the floor to protect the woodwork from danger of fire. For the same reason, the exhaust pipe, if placed on a wooden floor, should rest on bricks or similar material. If the exhaust outlet ends in a vertical pipe, it is advisable to place an elbow at the top end, to prevent water or solid obstacles from getting into the pipe.

26. Piping for Gasoline.—Considerations of safety, embodied in the regulations laid down by the National Board of Fire Underwriters, require that the supply tank of a gasoline engine be placed about 30 feet from the building, and below the level of the engine-room floor, making it impossible for the gasoline to flow to the engine by gravity. Such an arrangement is shown in Fig. 4, with the engine at *a*, the gasoline tank at *b*, and the pump at *c*. The tank *b* should be so placed that the bottom of the tank will not be more than 5 feet below the level of the pump *c*, as, owing to the nature of gasoline, it cannot well be raised through a greater height even with a well-constructed pump. The supply pipe *d* is attached at the bottom of the tank, and should have a constant rise toward the engine. The tank is placed preferably in a brick-lined vault, large enough to allow access to the valve *e* or other valves in pipes near the tank. The overflow pipe *f*, through which the gasoline returns from the cup *g* to the tank, enters the tank above the supply pipe *d*. A drain cock must be placed at the lowest point of the tank, to allow any water that may accumulate there to be drained off. Moreover, the gasoline may contain a little water, which, being heavier, will settle to the bottom of the tank, and in time will increase in quantity to such an extent as to be drawn into the engine and cause it to stop.

27. Stop-cocks should be provided in both supply and overflow pipes near the tank. They may be closed, so as to allow the pipes and connections to be examined without having to empty the reservoir. A stop-cock in the supply pipe, to be closed when the engine is shut down overnight, has the additional advantage of keeping the pipe filled

with fuel and obviating the necessity of having to pump it up by hand before starting the engine in the morning. It is very important to have all joints in the gasoline pipes perfectly tight. Galvanized pipe and fittings should be used and all screwed joints soldered. Before the pipes are put in place, they should be thoroughly cleansed of any impurities by washing with kerosene. All pipes and fittings should be carefully examined to make sure that they show no defects, such as imperfect seams or blowholes, that would admit air into the pipe and prevent the pump from lifting the gasoline.

A filter, shown at *h*, Fig. 4, is usually furnished with the engine; it should be placed in the supply pipe before the point where this pipe enters the pump. Neglect in supplying a filter may result in impurities being washed out of the pipe, settling under the pump valves, and interfering

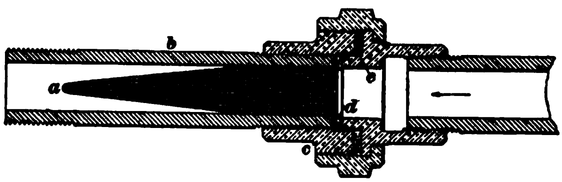


FIG. 5

with the action of the pump. In case no filter is supplied by the maker of the engine, it is well to provide one. In Fig. 5 is shown a good form of filter, which is made of fine-wire gauze *a* inserted in a short nipple *b* and held in place by a standard brass union *c*, the gasoline passing through in the direction of the arrow. The gauze is held in place by a brass ring *d*, and the joint is made tight by a leather washer *e*. In running the gasoline pipe to the engine, care should be taken to keep it away from the exhaust pipe, as the heat from this pipe would interfere with the flow of gasoline by producing a quantity of gas in the pipe that would prevent the liquid from being pumped up into the engine. Gasoline pipes that are placed under ground should not be covered with earth until a test has proved that they are perfectly tight.

It is well to make sure of this by starting up the engine, keeping it running for a day or two with the pipes exposed, and watching for leaks. To facilitate taking down any pipe connections near the engine or disconnecting the tank, use brass unions in the gasoline pipes near the pump and the tank.

COOLING SYSTEM

28. Temperature of Cooling Water.—In a well-constructed gas engine having ample cooling water space around the cylinder and valve-casing, the water supply should be so regulated as to maintain a temperature of about 160° to 180° F. This temperature will prevent excessive heating, which would interfere with the proper lubrication of the piston and cylinder and with the easy operation of the valves and igniter, as well as destroy the packings between the cylinder and the valve casings, where such packings are employed.

Keeping the temperature of the cooling water much below 160° F. would have an injurious effect on the condition of the piston and cylinder, and prevent getting the best results from the engine, even with a proper combustion of the mixture in the cylinder. If the water when it leaves the cylinder is practically cold, the cylinder will be cooled to such an extent as to cause condensation of the exhaust gases, resulting in corrosion, undue wear of the piston, and sticking of the piston rings, and a large amount of heat that should be utilized in doing work will be carried away by the water.

29. Tank System of Cooling.—For engines of small or medium size, cooling by means of a water tank, as shown in Fig. 6, is most efficient and least expensive. When employing a tank of proper size, the question of keeping the water at the proper temperature is easily solved. The amount of water that must be added in this system of cooling is limited to the small quantity that is lost by evaporation. The essential points to be observed in making connections between the engine and the tank are as follows: The tank must be of such shape that the opening for the pipe *a* at the top

is at least 3 feet above the top of the engine cylinder *b*. Th pipe must be of ample size, so as to afford little obstructio to the circulation of the water. The water should be take from a convenient point immediately above the bottom o the tank, and should enter the cylinder jacket at the bottom and leave at the top. The level of the water in the tank

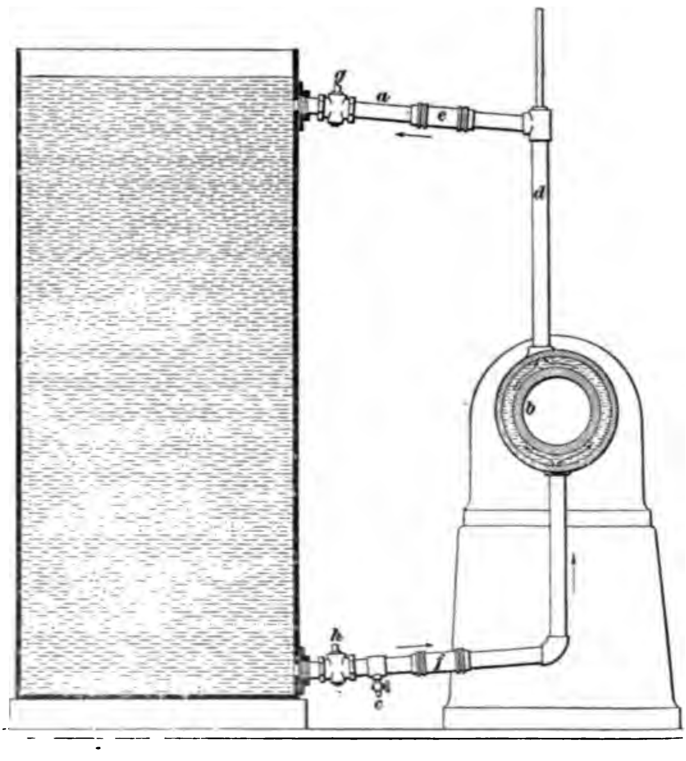


FIG. 6

should always be several inches above the entrance of t water pipe *a* near the top of the tank. A drain cock *c* shou be placed at the lowest point of the pipe, to allow the water be drawn off in cold weather, and thus prevent freezi and consequent bursting of the water-jacket. The vertic pipe *d* from the jacket to the tank should be extended fro

6 to 12 inches above the water level in the tank, as shown, to allow for the escape of air and to facilitate the circulation. Where the engine is not placed on a rigid foundation, short pieces of rubber hose *e*, *f* should be inserted in the horizontal pipes at top and bottom, so as to prevent the communication of any vibration from the engine to the tank. The valves *g* and *h* permit the tank to be shut off when the cylinder jacket must be drained.

30. The capacity of the cooling-water tank for an engine running under an approximately full load may safely be put at 50 gallons per horsepower. For large engines, above 20 horsepower, the tank system of cooling may be successfully employed, if supplemented by a circulating-water pump driven from the engine or any part of the line shaft. The pump must be so set and connected as to take water from the bottom of the tank or cistern, force it through the jacket, and return it to the tank. If the cistern or tank capacity is limited, which is likely to be the case in large installations, the use of suitably constructed air-cooling arrangements is necessary. These arrangements generally consist of a series of slanting surfaces, one below the other; the water, after passing through the engine, is delivered by the pump to the top of the cooler, and descends by gravity, flowing over the surfaces and being cooled by contact with the air, before it returns to the tank or cistern. The capacity of the water-circulating pump should be about 15 gallons per horsepower per hour.

31. Cooling by Steady Water Supply.—Where a steady supply of cold water from water mains or any other source is convenient and inexpensive, the supply pipe can be of smaller size than when using the tank or circulating system of cooling. A ½-inch pipe at moderate pressure will supply enough water for a 5-horsepower engine and a 1-inch pipe is sufficient for a 40-horsepower engine, larger engines requiring proportionately larger supply pipes. The water supply pipe, shown at *a*, Fig. 7, should enter the engine at the point that is likely to heat most rapidly, generally at the

exhaust-valve casing or cylinder head, and the outlet pipe *b* should emerge from the top of the cylinder jacket. The outlet pipe should discharge into a funnel *c*, in order that it may readily be seen whether the water is flowing or not, and that the temperature of the water may be better observed. The overflow pipe *d* should be one or two sizes larger than

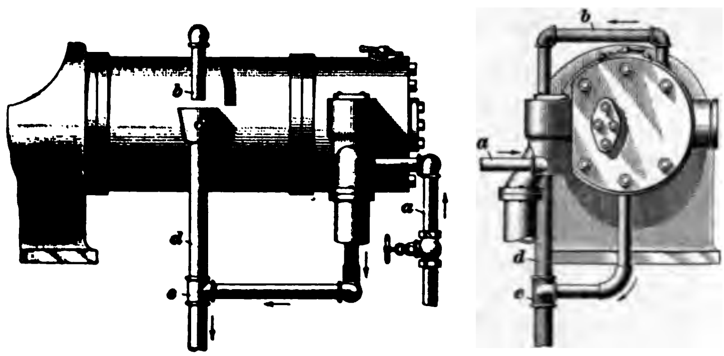


FIG. 7

the supply pipe, in order that all the water that is brought to the engine under pressure may flow off by gravity. Provision should always be made by a suitably placed drain connection *e* for emptying the cylinder jacket in cold weather, to guard against cracking of the jacket walls through the freezing of the water.

32. Deposits in Water-Jacket.—If the cooling water contains lime or alkali, the heating of the water in the jacket will cause these solid substances to be deposited in the cooling spaces. This will soon choke any narrow ports and prevent proper circulation, resulting in overheating, rapid wearing of the valves, and loss of power and efficiency. A simple remedy consists of the application, at regular intervals, of a dilute solution of hydrochloric, or muriatic, acid, made as follows: Dilute one part of muriatic acid with nineteen parts of water, and, after draining the jacket completely, pour in enough of the solution to fill the entire cooling space. Allow the mixture to remain in the jacket for not more than 8 to 12

hours, after which wash the cooling space thoroughly by running clear water through it. If the solution is permitted to remain in the jacket longer than the period stated, there is danger that the metal may be damaged by the action of the acid. The acid will soften and dissolve the lime or alkali, and the clean water will remove it from the jacket. It is generally sufficient to apply this method of removing the deposits once every two weeks. If neglected too long, the acid will not dissolve the deposit.

ASSEMBLING ENGINE AND ADJUSTMENT OF PARTS

33. Shaft and Flywheels.—Before assembling any parts of the engine, they must be thoroughly cleaned of any dirt, dust, antirust, or packing material, and lubricated where necessary. After the engine bed has been securely placed upon the engine foundation, the working of the crank-shaft in its bearings should be examined to see that it turns easily. Only very small engines are usually shipped with the shaft in place and the flywheels keyed to the shaft. If the wheels are shipped separately, they should not be put on the shaft until it has been ascertained that the latter does not bind in the journal-boxes. When lifted by hand, the crank should drop by its own weight from a horizontal position. The timing of the valves and igniter depends on the relative position of the teeth in the gears on the crank-shaft and cam-shaft. As a rule, the gears are marked by ciphers or similar symbols, and must mesh so that the mark on the tooth of one gear comes opposite to a like mark on the space between two teeth of the other gear. This should be investigated before any attempt is made to put the wheels on the shaft.

34. See that the bore of the flywheels and the surface of the crank-shaft are clean. Then oil both parts with lubricating oil. Usually each wheel and each key is numbered, and care should be taken to place them so as to go on the side marked with corresponding numbers on the end of the

shaft. If the weight of the wheels makes lifting by hand impossible, place planks on the floor underneath the crankshaft, and roll the wheels up on these planks until the bore of the hub stands exactly opposite the end of the shaft. Then work the wheel gradually over toward the shaft until it rests against the end of the shaft. By a concerted effort of the men handling the wheel, it will then be easy to slide the wheel on the shaft for a distance of an inch or more. Now place a block of wood between the crank and the engine bed, so as to prevent the crank from moving when turning the flywheel to the right. Be careful, however, to place the wood so as to avoid danger of breaking the bed. Then, while one or two men hold and balance the wheel, turn it slowly and gradually around on the shaft toward the right, at the same time pressing it on the shaft until it is worked on the shaft the full length of the hub. Remember that the wheel has been on the shaft before, and if it is found that it sticks and refuses to turn, look for obstacles such as dust or chips, and take off the wheel at once before the bore of the wheel and the surface of the shaft are damaged by cutting.

35. After the wheel has been put on the whole distance, turn it so that the keyway in the wheel stands exactly opposite the one in the shaft, and drive the key in by means of a sledge or a large-sized hammer. The keys should be well lubricated before being driven. If two keys are used in one wheel, drive them in gradually and evenly. Driving in one key at a time, all the way, will result in throwing the flywheel out and prevent it from running true. Care should be taken in striking the ends or heads of the keys with a hammer, as they may break off if not struck squarely.

It is sometimes found, after placing the wheel on the shaft, that it does not run true. This may be due to careless handling in shipping or unloading. The damage can be repaired and the wheel made to run true by careful hammering of the spokes near the hub. To ascertain which part of the wheel needs straightening, turn it slowly by hand, holding a piece of chalk on a rest close to the rim, thus marking the

higher part of the rim. Then strike the spoke or spokes under this part of the rim with the blunt end of a medium-sized hammer. To avoid injuring the paint, hold a piece of sheet copper against the part of the spoke with which the hammer comes in contact, and strike a spot about 2 or 3 inches distant from the outside of the hub.

36. Piston and Connecting-Rod.—The piston and connecting-rod are generally shipped detached, and, even if they are in position when the engine is received, it is advisable to disconnect the rod, take out the piston, and thoroughly examine both. Remove all antirust material used in packing by washing the surfaces in kerosene and rubbing with cotton waste. See that the outer surface of the piston is smooth, and that the edges have not been damaged in handling. If necessary, smooth off any slight ridges with emery cloth or a very smooth file. The closed end of the piston, which is exposed to the combustion, must be smooth and must not show any imperfections in the casting, such as blowholes or sandholes. Defects of this nature may easily cause premature ignition of the charge.

The piston rings should move easily in their grooves, without, however, any lateral play. If they stick, use kerosene freely, until any gummy oil or material has been washed away. If the piston pin that holds the piston and connecting-rod together is lubricated through a hole in the wall of the piston, see that this hole is clean and affords no obstruction to the flow of oil to the pin.

37. Clean both bearings of the connecting-rod, and after cleaning and giving a liberal coat of oil to the piston pin, insert it in the piston, with the rod held in place between the bosses inside of the piston. The inner walls of the latter should be free from any trace of molding sand, turnings, or filings that might find their way into the cylinder and cut the working surfaces. It is good practice to give the rough inner piston surface a coat of black fireproof asphaltum paint before the piston is placed in the cylinder. This should properly be done by the maker of the engine, but, if neglected, it

will benefit the purchaser to have it attended to before any attempt is made to start the engine. Clean the interior of the cylinder and examine the condition of the working surface to make sure that it is in perfect condition and shows no longitudinal scratches or ridges caused by the cutting of the piston.

38. After the piston pin has been inserted, tighten the setscrews and locknuts used for holding the pin in place. Apply a liberal quantity of cylinder oil to the outer surface of the piston, which is now ready to be placed in the cylinder. The end of the cylinder nearest the crank-shaft is usually tapered, so as to make it from $\frac{1}{8}$ to $\frac{1}{4}$ inch larger in diameter than the piston, to facilitate the insertion of the latter into the cylinder. The piston rings, being naturally expanded, must be compressed so as to enable them to enter the cylinder. In small engines this can be done by hand, while in larger pistons, it will be found more convenient to use cord or thin flexible wire with which to draw the rings together.

39. After the piston has completely entered the cylinder, move it backwards and forwards several times to ascertain whether or not there is any obstruction to prevent it from working freely. The cap of the crankpin bearing of the connecting-rod having been removed, the crank is now turned so as to bring the crankpin opposite its bearing, and the rod and piston are moved out until the bearing rests against the pin. Then put on the connecting-rod cap and tighten the bolts until the bearing is properly adjusted. Always use a liberal amount of lubricating oil on both pin and brasses before putting them together.

40. Valve-Gear Shaft, Valves, and Governing Mechanism.—In most cases either the crank-shaft or the secondary or cam-shaft is shipped detached from the engine, and must be put in place by the erector. As the time of opening and closing the inlet and exhaust valves, as well as the point of ignition, is determined by the cam-shaft, it is obvious that there is a certain relative position of the gears that drive

the secondary shaft. These gears may be spiral, spur, or bevel gears, but in any case it is necessary that the teeth of the gears mesh so as to time the valves and igniter properly. This time having been determined at the factory when the engine is assembled and tested, the maker generally marks the gears by letters, ciphers, or similar marks, one on the tooth of the driving gear, and a corresponding mark on the space between the teeth of the driven gear.

41. When placing the shafts in their bearings, be sure to look for these marks, and put the gears together so that they mesh as intended. The maker of the engine is of course supposed to know the exact timing of the valves and igniter that will give the best results obtainable with his particular engine, considering its design, speed, etc., and no attempt should be made by the purchaser or attendant to improve the engine in this respect. Generally speaking, however, the exhaust valve should close at a point when the crank-shaft has passed the inner dead center, after the end of the exhaust stroke, by from 5° to 10°. The length of the cam or other similar device used for operating the exhaust valve will then determine the point of opening, which, in an engine of moderate speed, will be about 40° to 45° before the crank reaches the outer dead center on the working, or expansion, stroke.

The inlet valve, if operated by a cam or a lever, generally opens a little before the beginning of the suction stroke, possibly 5° to 10°, so that for a very short period of time both inlet and exhaust valves are open, say during 10° to 20° of the crank movement. The inlet valve will generally be found to close, when the crank has passed the outer dead center, at the end of the suction stroke—to an extent of from 15° to 30°, depending on the fuel and other conditions. If operated by the partial vacuum inside of the cylinder, created by the outward movement of the piston during the suction stroke, the inlet valve of course opens and closes automatically, and the timing is regulated by the tension of the inlet-valve spring.

42. The timing of the fuel-admission valve, where the valve is mechanically operated by cam and lever or some similar device, depends on the kind and quality of fuel used, and also on the pressure at which it is supplied. With illuminating gas at the average pressure, the valve should open when the crank has passed the inner dead center about 15° and close about 30° after the crank has passed the outer dead center. The same timing of the air-inlet and fuel valves will be found to give the best results when using gasoline as when using illuminating gas, if the gasoline is supplied through a nozzle controlled by a small poppet valve actuated by cam and lever.

43. As natural gas is much superior to illuminating gas in heating value, a differently proportioned mixture is required, which is usually regulated by throttling the gas-cock on the engine so as to suit the quality of the fuel available. The timing of the fuel valve is the same, however, as when using illuminating gas. But the poorer qualities of gas, such as producer gas or fuel of correspondingly lower heating value, require a longer period of time during which the gas valve must be open. Generally, it will be found that, in order to get good results, the valve must begin to open at about 15° before the crank passes the inner dead center, previous to the suction stroke, and remain open until the crank has passed the outer dead center about 40°. As stated before, these angles are only approximate, and they vary slightly according to the design of the engine, the area of the valves, and the speed at which the engine is operated.

44. After the cam-gear shaft has been properly placed and secured in its bearings, turn the engine over slowly and see that the shaft and the parts actuated by it move freely. Attach any levers, links, or rods that may not be in place when the engine is taken from the boxes, lubricating all pins and pivots carefully before putting them together. See that any valves closed by springs come to their seats quickly if pushed in by hand and released. Apply a liberal amount of kerosene to all valve stems, so as to remove any gummy

or similar matter with which they may have become coated. Give special attention to the governor, on whose free movement depends the regularity of speed of the engine. All links and pivots connected with the governing mechanism should be washed with kerosene and then lubricated with a light oil of good quality.

45. Attachment of Lubricators.—Before attaching the lubricators furnished for oiling the cylinder, bearings, and principal moving parts of the engine, the oil cups should be carefully examined for any dust or other impurities that they may contain. See that they are perfectly cleaned before they are put in place and filled with oil.

The tapped holes for receiving the individual oil cups and the holes through which the oil is supplied to the parts to be lubricated should also be examined with great care, and any waste or similar obstructions that would tend to interfere with the supply of oil should be removed.

IGNITION SYSTEM

46. Battery and Spark Coil.—The matter of installing the battery, spark coil, switch, and wire connection deserves the most careful attention. The battery cells should be charged and the wire connections between the battery and the engine made according to the instructions sent with the particular make of battery used in connection with the engine to be installed. As a matter of fact, the larger part of the trouble with internal-combustion engines is due to the igniter and its connections. Some of these difficulties will occur if every possible care is taken, but most complaints can be traced to neglect or carelessness in installation or ignorance in operation.

As the make-and-break contact system is used almost exclusively on stationary engines, only this method will be considered at present. A good quality of insulated fireproof and weatherproof copper wire should be used to connect the individual cells of the battery and the spark coil

with the battery and engine. Flexible rubber-covered or stranded wire is also permissible. In fastening the wires to the ceiling or walls, do not use metal clamps, which are liable to injure the insulating material, but use wooden or fiber cleats cut out to suit the thickness of the wire. Avoid splicing whenever possible; but, if it is necessary to employ splices, make them carefully and solder them securely. The wire should be of such length as to reach from 6 to 9 inches beyond the binding post to which it is to be connected. To avoid any pulling on the wire or post, the extra length should be coiled on a $\frac{1}{4}$ inch round rod, slipped off, and left as a spiral between the straight wire and the binding post.

47. Electrical Connections.—The spark coil must be set in a dry place and must be well protected from moisture, which causes short-circuiting and prevents ignition. All terminals of the wire connections must be clean and bright, to insure good contact. The connections between the cells should preferably consist of flexible insulated wire, with flat copper washers soldered to the ends, the hole in the washer fitting easily on the binding post. Connections of this kind may be purchased from almost any electrical supply dealer, if they are not already furnished with the engine.

As a rule, an ordinary two-pole, or two-point, switch, with lever-handle contact will answer all purposes. These switches have the advantage of being easily examined and kept in order. Knife switches are equally well adapted for use in engine rooms, while if the switch is necessarily exposed to out-of-door atmosphere an enclosed switch, such as is used for incandescent lights, is more suitable.

48. Ignition Plug.—The ignition plug containing the electrodes must be examined as to cleanliness, freedom from corrosion, especially of the contact points, and easy movement of the movable electrode, before being attached to the combustion chamber. While the engine is at work, the plug, being exposed to the heat of the combustion, will expand slightly more than the surrounding walls. It is evident, therefore, that in order to be able to remove the plug

in case of necessity, after the engine has been running for some time, it must, when cold, enter its aperture easily and without having to be forced. The packing surface of the plug, making it tight against the pressure in the cylinder, is a ground joint, either flat or tapering, or a flat ring-shaped surface packed with sheet asbestos. In either case, the packing surfaces must be thoroughly cleaned before the plug is put in place and tightened up.

49. Point of Ignition.—The point of ignition varies in accordance with the quality of the fuel and the speed of the engine. At medium speed, when using illuminating gas or gasoline, the ignition should occur just before the end of the compression stroke, with the crank standing at about 15° to 20° below the inner dead center. Natural gas, as well as producer gas, the combustion of which is somewhat more sluggish, requires a different timing of the igniter, and the spark should occur when the crank stands about 22° to 25° below the inner dead center.

50. Testing the Electrical Connections.—The testing of the electrical connections may be said to complete the installation of the engine and put it in condition for starting. To determine whether the wires transmit the current in the proper manner, connect the battery, spark coil, switch, and engine as directed. Then disconnect the terminal attached to the fixed electrode, turn the engine to such a position that the two electrodes will be in contact, see that the switch is turned on, and wipe the end of the wire against the surface of the nut that holds the fixed electrode in place. If everything is in good order, a bright spark will then be produced. On the other hand, after turning the engine so that the contact between the two electrodes is broken, no spark should appear when the fixed electrode is touched and wiped in this manner; in wiping any other bright part of the engine, however, a spark of similar intensity to that just referred to should be produced.

STARTING THE ENGINE

PREPARATIONS FOR STARTING

51. Adjustment of Lubricators.—After the engine has been assembled and connected, the oil cup should be filled and tested to ascertain that the feeds work properly. The adjustment of the cups should at first be such as to supply a rather liberal number of drops; later, the quantity of oil may be cut down to the normal amount, after it has been demonstrated that the bearings run cool. In a vertical engine using splash lubrication, fill the oil well in the base until the ends of the connecting-rod bolts dip about ½ inch into the oil when the crank stands at its lowest point. Make sure that all links, levers, and pivots have been lubricated, that the valves and igniter move freely, and that the water supply, if taken from the mains, is circulating properly.

To make certain that the crankpin and the piston pin are properly lubricated before starting, apply a small quantity of oil to each by hand, without relying on the lubricator or mechanical oiler provided for the purpose of oiling these parts while the engine is running. Sometimes these devices may fail to perform their functions as promptly as is necessary, and a hot bearing may result, causing serious trouble that could have been easily avoided by taking this simple precaution.

52. The oil wells of the ring-oiling bearings should be filled to the proper height, and it should be ascertained that the oil ring or chain moves freely, so that it will distribute the oil over the journal surface when the shaft revolves. Wiper oilers must be adjusted so that the moving element of the device touches the stationary part of the oil cup only lightly enough to wipe off any drops of oil suspended from the metal tip or wick of the feeding device. If the wiper scrapes too hard against the tip of the cup, it will waste oil and throw it over the engine.

Worm or spiral gears, which are often employed to transmit motion from the crank to the cam-shaft, are usually run in an oil bath. The casing containing these gears must therefore be filled with oil before starting.

53. Examination of Piston.—Examine the way in which the piston works in the cylinder. A proper fit of the piston is of the utmost importance, in order to obtain good service from the engine. It must move freely, but at the same time must prevent any loss of pressure during the compression and expansion strokes. When turning the engine by hand, there must be no hissing sound during the compression; this would surely indicate a defective piston or improperly fitted piston rings. A perfectly fitted piston, tried in this way, will rebound before the end of the compression stroke is reached.

54. Examination of Valves and Igniter.—If the engine can be turned over easily through the compression stroke, it will be difficult or impossible to start it. The loss of pressure, however, which prevents proper compression, is not likely to be due to an imperfect piston, especially in a new engine, but rather to a valve that leaks or to leakage about the movable electrode. It is well, therefore, to ascertain the cause of such a leak, by thoroughly examining the inlet and exhaust valves and the igniter. Possibly one of the valve stems or the electrode may stick in the guide, or there may be an obstruction on one of the valve seats. Where packings are used, one of them may have been damaged or partly blown out.

An application of kerosene to the valve stem will wash away any thick oil, grease, or similar substance that may cause the valve to stick. If impurities have been deposited on the valve seat, they can usually be removed by lifting the valve by hand and cleaning the seat with a scraper or some similar tool. In the case of larger valves seated in casings too heavy to be handled conveniently, the valve may have to be taken out before the seat can be examined and cleaned.

The renewal of a packing, especially when the packing

surface is of considerable size, is a more serious matter, and should not be undertaken until a careful examination has shown the necessity for doing so.

55. Adjustment of Ignition Device.—Where an incandescent metal tube is used for igniting the charge, this tube must be brought to its proper temperature before the engine can be started. The heating devices used in connection with these tubes differ according to the fuel employed. In any case, however, whether the fuel is gas or gasoline, the burner must be so adjusted that a sufficient quantity of air is supplied to obtain a hot blue flame. A yellow flame indicates a lack of air. The degree to which the tube is heated not only influences the point of ignition but also has a material effect on the life of the tube.

Iron tubes, while less expensive, do not last so long as tubes made from special nickel alloys; but, in either case, the life of the tube is shortened by overheating. This will readily be understood when it is remembered that overheating causes the tube to become soft, in which condition it cannot resist for any length of time the high explosive pressure, which has a tendency to burst the tube. Generally, the most favorable condition in regard to the proper timing of the ignition and the longest possible service is reached if the tube is heated to a bright cherry red.

The preparation of electric-ignition devices previous to starting the engine has already been explained. The engine having been properly assembled and connected, the lubrication having been attended to, the valves moving freely and seating tightly, and the means of igniting the charge being in good working order, the engine may be considered ready for starting.

56. Means of Starting.—Small engines are often started by hand, simply requiring the opening of the fuel cock and the turning of the flywheel until the charge thus admitted is ignited, giving the engine an impulse sufficient to carry it over the following strokes of its cycle until subsequent charges are admitted and ignited. In this manner,

the engine reaches its full speed when from ten to twenty explosions have taken place, the number of explosions depending on the weight of the flywheel. An engine equipped with heavy wheels requires, naturally, more impulses before attaining full speed than one with light wheels.

57. Difficulties in Starting.—Difficulties in starting usually met with in practice may be due to various causes. Above all, it must not be supposed that an engine that has run regularly for a period of time will refuse to run without cause, and the origin of the trouble should be located as speedily as practicable. The most common sources of trouble in starting are improper proportion of the constituent parts of the mixture, failure of the igniter and its connections, or loss of pressure during the compression and expansion strokes. A proper proportion of air and fuel is of great importance to prompt and effective combustion. It should be remembered that when starting by hand, with the piston moving slowly, the fuel valve remains open for a longer period of actual time than when the engine is running at its normal speed. The fuel being usually supplied under a certain amount of pressure, while the air is drawn from the atmosphere, it follows that, with the engine turning slowly, the proportion of fuel to air is greater under these conditions than under normal working conditions. This condition is made still worse when the inlet valve is of the automatic type, being opened by the partial vacuum created in the combustion chamber by the outward movement of the piston.

58. Regulation of Mixture in Starting.—In order that the quantities of air and fuel may be regulated so as to admit a mixture of the proper quality, the fuel cock should be only partly opened during starting. The cock or throttle being usually fitted with a graduated dial, the operator will be able after a few trials to determine at which point of opening the engine will start readily. When using illuminating gas, this point will vary in accordance with

fluctuations in pressure that may occur at different times of the day.

A common mistake made by inexperienced operators is to admit too much fuel to begin with, and if the engine naturally fails to ignite, to still further open the fuel cock and thus aggravate the trouble. This applies equally well to gaseous and to liquid fuels. As a result of opening the fuel supply too wide, the combustion chamber becomes flooded with gas or vapor, and conditions are not improved until the supply has been shut off completely and the engine turned over several times, so that the contents of the cylinder are expelled through the exhaust pipe.

59. When operated with illuminating gas, it will generally be found necessary to first open the valve in the pipe back of the gas bag, let the bag become inflated, then shut off the valve, and start the engine on the pressure exerted by the gas contained in the bag and pipe between it and the engine. As soon as the bag shows signs of becoming empty, which will occur after a few explosions, the fuel cock must of course be opened.

When using gasoline, the air can vaporize only a certain quantity of fuel. Any excess will be deposited and will accumulate in the inlet passages and in the combustion chamber, and the longer the wheels are turned with this excessive opening of the fuel supply, the more aggravated will the trouble become. Frequently, if under these conditions the fuel supply is shut off completely and the turning of the wheels continued, an explosion will occur as soon as the amount of fuel carried into the cylinder is reduced to the point when a properly constituted mixture is formed.

60. In a well-designed engine, the fuel cock is proportioned so that it must be opened full, in order to obtain a perfect mixture with the engine running at full speed. Engines with air-inlet valves positively operated by means of cams and levers are less liable to failure in starting caused by improper proportions of the mixture. This is due to the fact that in such engines the air-inlet valve and the

fuel valve are open during the same period of time, thus regulating to a certain extent the quantities of air and fuel forming the charge.

61. In engines operated on liquid fuel, such as gasoline, kerosene, etc., the fuel must be pumped by hand until a sufficient quantity is raised from the supply tank to the level of the fuel-admission valve to start the engine. The fuel is generally pumped into a small cup provided with an overflow pipe, which returns to the supply tank any excess amount of fuel over that which fills the cup to a certain level. This cup and overflow device may be a part of the fuel valve or it may be separate.

When first starting the engine, it may require quite a number of strokes of the fuel pump before the air in the suction pipe between the tank and engine is pumped out and the liquid delivered to the valve. If there is difficulty in pumping the fuel, it is a sure sign of leakage of air in the supply pipe; if the liquid does not stay in the cup after being pumped up, it indicates that there is leakage at some point between the cup and the engine. Before attempting to run the engine, therefore, the pipes and connections should be carefully examined, the leak located, and any imperfect joints made tight.

62. In the modern gasoline engine, a mechanically operated device, which determines the exact amount of fuel sprayed into the air, atomizes the gasoline while entering the mixing chamber at a certain velocity. It is therefore evident that the forming of a proper mixture and the consequent prompt starting are not dependent on atmospheric conditions and quality of the fuel to the same degree as when the old type of vaporizer was used. Nevertheless, in extremely severe weather, in locations where the engine room is not kept warm during the night, and especially when the fuel used is of comparatively low specific gravity, it may become necessary to aid the atomizing of the gasoline by heating the combustion chamber in some manner before starting can be attempted.

The fuel is sometimes heated by removing the inlet- or exhaust-valve cover and placing a quantity of cotton waste soaked in kerosene in the combustion space and lighting the waste, but this is a crude and dangerous proceeding and cannot be recommended. In addition to the danger connected with an open flame, the burning of waste may easily result in leaving in the chamber fragments of the material, which may be drawn into the cylinder and interfere with the proper working of the piston, valves, and igniter. An absolutely safe way of accomplishing the desired object is to fill the empty water space in the jacket with hot water prepared for this purpose. This will increase the temperature of the walls surrounding the combustion chamber sufficiently to aid in the vaporization of the fuel and make prompt starting more certain.

63. No set rules can be laid down that will tell the operator just how to obtain a perfect mixture at all times. This depends on the design of the engine and on the conditions surrounding each individual case, which may necessitate a different method from that which must be observed in another engine of the same type or make. Indications of a good mixture will manifest themselves to an observant operator by the sound of the impulse and the appearance of the exhaust at the end of the exhaust pipe. A smoky exhaust is a certain sign of an excessive amount of fuel, and a mixture of this kind also produces a weak impulse. If the exhaust is clear and it requires the admission of several charges in succession before an explosion occurs, the indications are that the fuel is not admitted in sufficient quantity. This condition also manifests itself by **back firing** or explosions in the air pipe and passage, caused by retarded combustion of the charge, the mixture being still burning at the end of the exhaust stroke and igniting the incoming charge while the inlet valve is still open.

64. Regulating Gas Pressure.—Engines operated with illuminating or natural gas require the same amount of judgment in determining the amount of fuel to be admitted

while starting the engine as does a gasoline engine. If illuminating gas is used, the pressure is regulated at the gasworks, and any slight fluctuations are equalized by use of a rubber bag, as already explained. When running with natural gas or producer gas, the pressure is frequently regulated by a small gasometer, as illustrated in Fig. 8, consist-

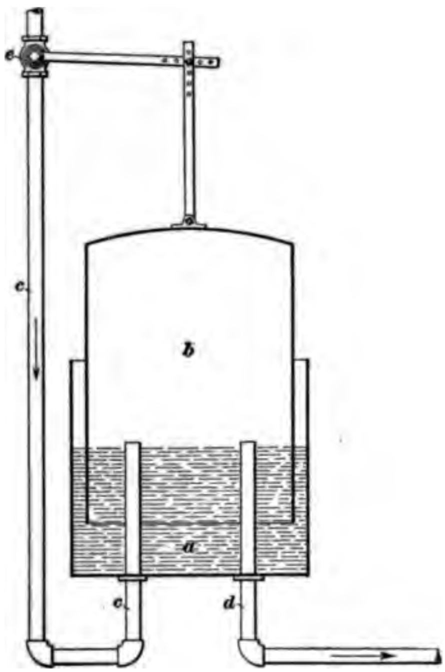


FIG. 8

ing of a tank *a* partly filled with water in which is submerged a float *b*, closed at the top and open at the bottom. The gas-supply pipe *c* from the main enters the gasometer at the bottom and extends through the water into the float, while the pipe *d* connecting the gasometer to the engine is attached in a similar manner. The float *b* is connected to the valve *e* in the supply pipe in such a manner that, when the float becomes filled with gas, it rises and closes the valve *e*. As soon as the engine takes a charge of gas from

the gasometer, the float *b* descends, and in doing so opens the valve *e* far enough to replace the amount of gas consumed by the engine. According to the existing conditions, the pressure exerted by the weight of the float may be increased by placing weights on top. The operator will learn by experience just how far the dial cock on the engine must be opened to make prompt starting possible.

65. Timing the Ignition.—A very important feature to be observed in starting an engine is the proper timing of the igniting device. This of course applies more particularly to electric ignition, as the hot-tube method is generally automatic in its action and is not timed by any mechanical device, but depends, for firing the charge at the proper moment, on the diameter and length of the tube and the temperature to which it is heated. Electric igniters are almost universally equipped with a retarding device that allows the breaking of the contact between the two electrodes and the resulting spark to occur after the crank-shaft has passed the dead center at the end of the compression stroke and to thus prevent the engine from turning backwards suddenly while the flywheels are being turned by hand. It is therefore necessary to be sure that the igniter has been set in starting position, to avoid possible injury to the operator. To lessen the liability to accident in case of unexpected reversing of the engine while starting, it is advisable to avoid placing the foot on the flywheel spokes when turning it by hand. If the engine is properly lubricated, and the relief valve generally provided for the escape of a part of the compression pressure during starting is working properly, it is always possible to turn an engine up to 30 horsepower by hand without putting the foot on the spokes.

66. This precaution in timing the point of ignition applies to electric ignition of the make-and-break contact as well as the jump-spark method. In the latter case, the timing device, which regulates the moment of ignition, must be adjusted so as to make the spark sufficiently late to

prevent reversing of the engine; hence a plainly visible mark of some kind should be provided that will tell the operator just how the timer must be set.

In case of failure to ignite, first see that the vibrator of the coil is working properly when the current is on. Also detach the wire connected to the plug, and test the distance the spark will jump by holding it close to any metal part of the engine. In doing this, it must be remembered that a spark will not jump as far when exposed to the high-compression pressure in the cylinder as it will in the open air. It should therefore be capable of jumping a gap of about $\frac{5}{16}$ to $\frac{3}{8}$ inch when tested on the outside of the cylinder.

If the spark is found to be satisfactory, take out the plug and examine the ends of the platinum wires, removing any carbon deposit or other impurities that may have accumulated there. Also see that the insulators are in good order, that they have not been cracked, and are free from grease; if necessary, cleanse them by washing with gasoline before putting them back in the plug.

CARE AND MANAGEMENT OF ENGINES

CARE OF ENGINE PARTS

67. In order to insure reliable service, an engine should be given the necessary care regularly. Those parts that contribute principally to the proper operation of the engine, such as the igniter, valves, governor, bearings, and lubricators should be inspected at regular intervals.

IGNITER

68. Under ordinary conditions of service, when running about 10 hours a day, the igniter should be taken out once a week, the contact points examined, and, if necessary, cleaned or dressed. There must be no leak past the seat of the

movable electrode, and as soon as any leak occurs at this point, as indicated by a hissing sound, the electrode must be taken out and ground to a perfect seat with fine emery powder and oil.

The stationary electrode is usually insulated with mica, porcelain, or lava washers or bushings, and packed with asbestos, so as to make it tight against the pressure of the explosion. If the packing of this electrode is damaged, the steel pin itself will be exposed to the intense heat of the burning charge. A gas leak will appear around the pin, and when trying to overcome this by tightening the nut at the end of the pin, the heated steel will be reduced in size. If this is repeated a few times, the pin will soon be useless. It is evident, therefore, that the fixed electrode must receive particular care in regard to preserving perfect insulation and tight packing. Mica insulators are probably best, as they are not liable to cause short circuits and consequent interruption of the service, by cracking, to which porcelain or lava bushings are subject. They also have the advantage of being sufficiently pliable not to require any asbestos washers to make them tight.

POPPET VALVES

69. There should always be a clearance of about $\frac{1}{32}$ inch between the end of the valve stem and the lever operating it, so as to make certain that the valve can come to its seat, even after it has become expanded by the heat while in operation. Repeated grinding will reduce the amount of clearance, and adjustment must be made by slightly withdrawing the setscrew usually provided in the end of the lever.

Inlet valves are naturally kept more or less cool and clean by the incoming mixture, and require grinding less frequently than exhaust valves. Inspection and thorough cleaning once a month, however, are advisable. Automatic inlet valves, opened by the suction during the outward stroke of the piston, must move freely in their guides; any deposit of

carbon or gummy oil will tend to interfere with their proper working. Kerosene applied to all valve stems at regular intervals will aid in keeping the stem clean and prevent it from sticking. The nuts and lock nuts on the end of the valve stem, which keep the spring in place, must be kept tight. Carelessness in this matter may cause the valve to be drawn into the combustion chamber, where it may cause serious damage to the cylinder or piston.

70. If the inlet valve is operated by cam and lever, the same precaution as to a small amount of clearance between the end of the stem and the lever must be observed, as referred to in connection with the exhaust-valve stem. The inlet-valve casing usually has in the cylinder head a ground joint that requires the same care as the valve seat.

When using gas, the fuel valve operates under much the same conditions as the inlet valve just referred to. The same directions for cleaning and adjusting will therefore apply to this valve. Gasoline poppet valves are often fitted with small stuffingboxes packed with wick saturated in a mixture of soft soap and graphite powder. Care should be taken to keep the stuffingboxes tight enough to prevent any leakage of gasoline past their stems, but not so tight as to prevent the springs from closing the valves promptly. It will be found that a brass gasoline-valve stem will give better service than a steel stem, as the packing material has a tendency to cause the latter to rust and stick.

GAS-COCK

71. The gas-cock, or throttle valve, generally consists of a cast-iron casing, a brass plug, and a graduated dial, with a handle to open and shut the cock. In order to be able to move the plug easily, it should be lubricated occasionally with a thin coat of oil and graphite. The screws that fasten the dial to the body of the throttle valve and hold the plug in position must be tightened evenly, so as to avoid leakage of gas at this point. When using natural or producer gas,

which is usually not so pure as illuminating gas, it will be found necessary to clean the gas-cock, as well as the gas-valve stem and casing, more often. Kerosene will be found useful for this purpose.

GASOLINE PUMP

72. Owing to the fact that gasoline vaporizes easily, it is more difficult to lift it by means of a pump than it is to lift water. The condition of the gasoline pump is therefore of great importance in getting good results from a gasoline engine. The plunger must be packed well with suitable material. Lamp wick or asbestos wick thoroughly saturated with a mixture of soft soap and graphite has proved an excellent packing for the stuffingbox of the gasoline pump. The valves, whether they are standard-type check-valves or flat-seated valves fitted with leather washers, must be kept free from impurities that may lodge on the valve seats and cause the pump to become air-bound, when it will naturally refuse to work. Filters used in the gasoline supply pipe, before it enters the pump, must be taken apart occasionally, and any impurities that may have gathered there must be removed, so as to afford a free passage to the fuel.

GOVERNOR

73. A steady speed is largely dependent on the working of the governor and its attachments. To insure good results in this respect, the levers and links of the governor must work freely, and at the same time there must be no lost motion in any of these parts. A thin lubricating oil should be used on all governor parts, and at regular intervals the whole governor should be taken apart, its pivots, levers, etc., cleaned by washing with kerosene or gasoline, and put together again after applying a liberal amount of lubricating oil. In most engines, the speed is adjusted by the tension of the governor springs, a higher speed being obtained by increasing, and a slower speed by decreasing, the tension of

the springs. It is not advisable to increase the speed of an engine beyond the normal number of revolutions without first consulting the manufacturer.

STARTING DEVICES

74. Self-Starters.—To obviate turning the flywheels by hand, which in engines of the larger size would be inconvenient, if not impossible, most builders equip engines of more than 40 horsepower, and sometimes even smaller sizes, with self-starting devices, consisting of hand pumps for compressing the explosive mixtures in the combustion chamber, and detonators or sparking devices for firing these charges by hand.

In a gasoline engine, the charging pump is usually attached to the side of the cylinder and is fitted with a small receptacle at the top or bottom containing a quantity of gasoline, over which the air is drawn before being forced by the pump into the cylinder. The air valve is automatic, and is held to its seat by means of a spring, the tension of which limits the lift of the valve and the amount of air pumped into the cylinder.

The charging pump of a gas engine takes the fuel from a small pipe connected to the gas supply, the gas being mixed with air while entering the pump cylinder through a series of small holes in the seat of the inlet poppet valve. Before charging the cylinder, the detonator, if one is used, must be charged with a parlor match, a portion of the wood being removed so that only the head end is inserted in the end of the detonator.

75. In order to start the engine properly, it must be turned until the beginning of the working or expansion stroke is reached. At this point of the cycle, the engine has just completed the compression stroke and the exhaust cam is about 180° away from the roller that operates the exhaust valve. With the crank in this position, the mixture is forced into the cylinder by giving a few quick strokes with

smaller number of drops than when full, and it is therefore well to always keep them filled. The temperature of the engine room also has some effect on the rate of feed, and in very cold weather the oil should be warmed before pouring it into the lubricators.

Force-feed lubricators supplying oil through tubes to the various bearings are more positive in their action in regard to the quantity supplied under varying conditions. Care should be taken, however, to guard against waste or other impurities settling in the bottom of the reservoir, whence they may easily be carried into the oil pipes and interfere with the free flow of oil to the parts to be lubricated.

80. Level of Oil in Crank-Case.—In engines using the splash method of lubrication the level of the oil in the crank-case should be maintained at a uniform height, as indicated by the gauge glass usually provided. While it is necessary to keep the oil level sufficiently high to insure good lubrication, it is equally important not to allow it to become too high, because in that case the surplus oil is carried past the piston, and is not only wasted but becomes a source of trouble by depositing itself on the igniter points and causing them to work irregularly. It may be observed, however, that the fitting of each individual cylinder and piston has some effect on the amount of oil thus carried into the combustion chamber. It will therefore be found that the oil level that must be maintained in order to get sufficient lubrication of the piston may vary in two engines of the same make and size, and in all cases great caution should be exercised to carry the oil up to such a level that there will be no doubt about sufficient lubrication. After the proper level has once been determined by experience, the oil gauge should be marked, so as to show at a glance whether the oil is up to the required height.

81. Pressure in Crank-Case.—In some vertical four-cycle engines that use the splash system of lubrication, the escape of oil past the main bearings, due to the pressure

produced by the movement of the piston, is guarded against by the use of a check-valve, a sectional view of which is shown in Fig. 9. The valve casing is attached to the crank-case, and the valve *a* is made adjustable, the tension of the springs *b* and *c* being varied so that the valve just closes the port *d* communicating with the crank-case when the engine is not running. When the engine piston moves downwards, the increase in pressure in the crank-case opens the valve, affording a relief for the surplus pressure. On the upward stroke of the piston, the partial vacuum closes the valve and prevents any air from being drawn in.

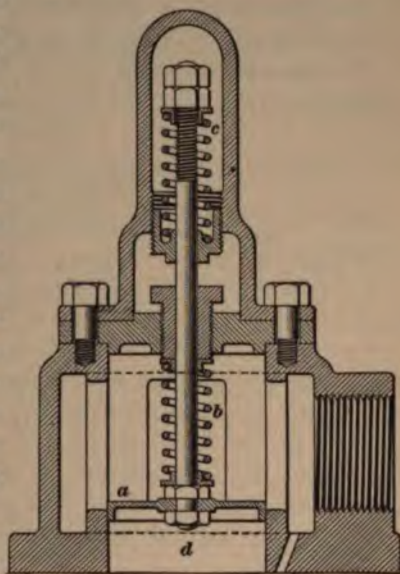


FIG. 9

82. Renewing the Oil.—The oil in the crank-case should never be left more than a week without inspection. Generally, it will have become thick and unfit for use by that time and should be removed. If there is a leak of exhaust gases past the piston, the oil in the crank-case will mix with the water from the gases and may become charged with acid from the sulphur that is present in these gases. This must be prevented, as the acid will gradually corrode and pit the journals of the crank-shaft and other moving parts with which it comes in contact.

ROUTINE OF MANAGEMENT

83. To avoid mistakes or oversights in starting, caring for, and stopping engines, the operator should adhere to a certain routine while performing his duties. The following rules in regard to the order in which the various operations in starting and stopping should be performed may prove of value.

STARTING THE ENGINE

84. 1. Attend to all lubricators and oil holes, always following the same order.

2. Apply a few drops of kerosene to the valve stems.

3. Open the gas-cock back of the rubber bag or regulator, or, when using gasoline, open the cock near the tank, and work the gasoline pump by hand until the liquid appears in the valve or overflow cup.

4. See that the electric igniter is properly connected; turn on the switch and see that the spark is of proper intensity; or, in case of tube ignition, light the burner that heats the tube.

5. Turn the flywheel until the engine is at the beginning of the working stroke.

6. Open the fuel cock to the point that has been found most reliable for starting.

7. Throw the relief cam in gear or open the relief cock.

8. If a compressed air or some other self-starter is employed, operate the device in accordance with the instructions given in previous paragraphs relating to this style of apparatus. If no starting devices are used, turn the flywheels rapidly until the engine starts.

9. Close the relief valve or disengage the relief cam and open the fuel cock to its full extent, gradually, as the speed of the engine increases.

10. Turn on the cooling water, if running water is used,

or see that the tank is full and the cocks open if the tank system of cooling is employed.

11. Throw in the friction clutch or shift the belt to the tight pulley on the line shaft.

STOPPING THE ENGINE

85. 1. Disengage the friction clutch or shift the belt to the loose pulley on the line shaft.

2. Close the gas-cock near the rubber bag or regulator, or the gasoline cock near the storage tank.

3. Close the gas or gasoline cock on the engine.

4. Throw off the switch between the battery and the engine, or turn off the burner that heats the tube.

5. Drain the water-jacket by closing the valve in the supply pipe and opening the cock that connects the bottom of the cylinder to the drain pipe. If water tanks are used, close the cocks in the water pipe and open the drain cock.

6. Shut off all sight-feed lubricators.

7. Clean the engine thoroughly, wiping off any oil or dust that may have accumulated on the engine.

8. See that the engine stops in a position where exhaust and inlet valves are closed. If necessary, turn the wheels by hand until this position is reached. It will protect the valve seats against corrosion.

TROUBLES AND REMEDIES

FAULTY OPERATION AND ADJUSTMENT

SYMPTOMS, CAUSES, AND CORRECTIVES

ENGINE-STARTING AND RUNNING DIFFICULTIES

1. Defective action is sometimes due to causes so apparent that explanations are unnecessary; hence, for the sake of convenience, all these possible sources of trouble have been grouped under the headings Causes of Refusal to Start, Causes of Misfiring, and Causes of Weak Explosions. In each case, the cause of the trouble may generally be traced in the last analysis to faulty ignition, a faulty mixture, or an insufficient supply of mixture. These broad, ultimate causes have been stated first, and the principal mechanical or electrical defects that produce the trouble are enumerated afterwards. It will be understood that these do not comprise all the possible troubles with engines. In particular, they omit entirely such matters as preignition, knocking, and overheating. The object of the following presentation is to enable the user to trace the difficulty when his engine refuses to give its normal power through some trouble, the nature of which is not immediately obvious.

2. It is a familiar fact that the internal-combustion engine is far more liable to stoppages and weaknesses, for reasons at first mysterious, than is the steam engine. The

explanation of this is that, while the steam engine is purely a mechanical apparatus, the internal-combustion engine is partly mechanical, partly chemical, and generally partly electrical in its functions, and the chemical and electrical parts of its organism may go wrong through causes not connected with the visible mechanism, or—as in the case of a badly adjusted trembler, a poorly working timer, or a leaky float—through mechanical derangements so slight as to escape notice.

From this it follows that, to manage successfully, an internal-combustion engine—especially one that works under such a variety of conditions, often very severe, as the automobile engine—it is first of all necessary for the operator to make good use of his reasoning faculties. The symptoms of derangement, when taken singly, are often such as may be caused by any one of several possible defects; in nearly every case the defect, whatever it may be, will produce several symptoms a careful study of which will lead to the elimination of causes that do not tally with all the symptoms; as, for instance, causes affecting all cylinders when only one or two are misbehaving, or vice versa. When the user has reached this point, generally a short further investigation of the points at which he has found trouble of that particular sort is most likely to occur will lead him to the discovery of the true cause. The cause of loss of power, due to such faults as a loose battery connection, a sticking inlet valve, or a bit of dirt in the carbureter, will at once be recognized in its true character by the experienced operator. The only way to attain final proficiency in these things is by extended experience with the particular engine in hand; but, on the other hand, there is absolutely no excuse for the aimless groping of many inexperienced users, who will often send needlessly for a tow, or will pull an engine to pieces in their search for some simple fault that might have been located by intelligent diagnosis.

3. Causes of Refusal to Start, or of Sudden Stoppage.—The fundamental reasons for an engine refusing to

run, or of a particular cylinder refusing to work, may be summed up as due to (1) no spark; (2) no mixture; or (3) wholly wrong mixture. These cover all the possible causes, which may be enumerated as follows:

1. Switch not closed.
2. Gasoline not turned on.
3. Carbureter not primed, or (rarely) primed too much.
4. Weak battery.
5. Gasoline stale or mixed with kerosene.
6. Gasoline too cold to vaporize.
7. Dirt or waste in carbureter or gasoline pipe.
8. Mud splashed into air intake.
9. Water in carbureter.
10. Soot on the spark plug or contact igniter.
11. Water on spark plugs.
12. Broken spark-plug porcelain.
13. Grounded wire (generally secondary).
14. Broken wire (generally primary), or loose connection.
15. Very bad adjustment of the coil tremblers.
16. Defective spark coil or condenser (rare).
17. Broken igniter spring.
18. Broken valve stem, spring, or key.
19. Valve cams slipped (rare).

4. Causes of Misfiring.—The principal cause of misfiring is irregular sparking, which may be due to a variety of causes. Irregular sparking may be caused by the following:

1. Soot on spark plugs or contact igniters.
2. Weak battery.
3. Broken wire, making intermittent contact through the vibration of the car (generally found in the primary circuit).
4. Loose connection to binding post (generally found in primary circuit).
5. Wire occasionally grounded through vibration of car. This is generally found in the secondary circuit, and it is not necessary for the bare wire to make contact with the

metal into which this secondary current is escaping. If the insulation of the secondary cable is weakened, and the cable is lying loosely on a metal part, the spark will often jump through the insulation.

6. Timer contact surfaces roughened by sparking.
7. Wabbling timer.
8. Poor trembler adjustment.
9. Trembler sticking at high speeds, due to inertia of heavy armature.
10. Insufficient pressure on timer contacts.

A sticking inlet valve, which stays open when it ought to close, will cause irregular firing and occasionally back firing. Another possible cause is a very lean or rich mixture ignitible only by a strong spark. It can always be distinguished from ignition troubles by the fact that the explosion impulses, when they occur, are of much less than normal strength. If the mixture is too weak, the explosions are likely to occur every other cycle.

5. Causes of Weak Explosions.—The causes of the explosions being weak are as follows:

1. Mixture too lean or too rich.
2. Leakage of compression.
3. Mixture diluted by exhaust gases.
4. Spark timing later than it should be, in one or all cylinders.

If the trouble is in the mixture, the explosions would be regular, unless the mixture is so far defective that it sometimes fails to ignite in spite of the spark occurring regularly. The same will be true in any case where, as is usual, the cause of the weakness is unconnected with any irregularity in sparking.

The principal causes of weak explosions may be enumerated as follows:

1. Dirt or waste in carbureter or gasoline pipe, causing weak mixtures.
2. Stale gasoline.
3. Air intake partially obstructed, causing rich mixture.

4. Bad carbureter adjustment.
5. Trouble with float.
6. Choked muffler.
7. Lack of oil on piston, or too thin oil.
8. Leak through valve (generally the exhaust valve).
9. Leaky spark plug.
10. Valve timing wrong. This is most likely due to the fact that the cam-shaft, etc., have been taken out and replaced with the gears in incorrect angular relation. It may, however, be caused also by wear of the cams, push rods, or valve stems, by spring in the cam-shaft or valve lifters, or by the slipping of cams.
11. Broken or worn piston rings.

6. A two-cycle marine engine may be running along smoothly and begin gradually to slow down. This condition may be caused by too much or too little gasoline; the ignition devices may have become disarranged; there may be too little cylinder or other lubrication, or too little water circulating through the cylinder jacket; something may be caught in the propeller wheel; in cool or cold weather, the moisture in the atmosphere may have become frozen by the rapid evaporation of the gasoline, thus preventing the free flow of air or the proper seating of the valve in the vaporizer controlling the gasoline supply and the flow of mixture from the crank-chamber; the piston and rings may have been fitted too snugly, causing them to bind in the cylinder, which may have become distorted by the different temperatures to which it is subjected, there being a comparatively cold inlet on one side of the cylinder and a hot exhaust port on the other; the exhaust ports, piping, or muffler may have become partly stopped by water, carbon, salt, or other deposits; the exhaust may have been submerged by a different trim of the boat, or there may have arisen conditions such as could not have been foreseen or provided against, and that might never again be experienced. At any rate, such slowing down is a forerunner of trouble and should be investigated. If the cause of the trouble cannot be

discovered, the engine should be stopped when it is safe to do so, the position of the boat being made such as not to endanger either boat or occupants through collision with passing craft.

7. The remedies for slowing-down troubles due to the causes just mentioned will in practice suggest themselves. In many cases, the cause of the difficulty can readily be determined and overcome. For instance, trouble due to an insufficient quantity of cylinder oil or circulating water might be attended to readily without stopping the engine, or a temporary stop might be made to remove a rope, grass, etc., from the propeller, or foreign matter from the sea-cock strainer or pump check-valves, or to adjust the ignition or replace a broken or weak valve spring. Structural troubles, such as tight pistons and distorted cylinders, would have to be attended to at some more opportune time.

If the vaporizer should freeze, it may be necessary to run the engine a while and then give the accumulation of ice and frost a chance to melt. If the water supply is insufficient and the jacket becomes overheated, it may be possible in case of an emergency to continue running by using a hand pump connected with the supply; or, with the supply open water may be pumped through or poured into the water discharge. In such case, the transformation of the water into steam might make it a little dangerous for the operator, and should the cylinder be too hot the water might possibly crack the cylinder at its weakest part, or at the point where it is subject to the greatest stress.

When it becomes necessary to run a four-cycle marine engine with too little circulating water, the compression should be relieved, the cooling action of the large quantity of gas, a part of which is wasted, helping to cool the cylinder, while the smaller amount exploded does not heat the cylinder as much as would full charges at the usual high compression pressure.

8. Irregular running of marine engines is a condition rarely encountered, and its cause is problematical. The

trouble may be caused by back pressure in the exhaust, or may be due to improper location, with reference to the exhaust port, of the transfer, or passover, port connecting with the crank-case; this could occur only in two-cycle engines. As a result of such improper location of the port, the engine cylinder might not be thoroughly scavenged of burned gases at high speed, when it would slow down to normal speed or slightly below, and, getting a better mixture at that speed, would speed up. It might also be caused by the exhaust ports opening too late or the inlet ports opening too early. It is well known that, with no thought of fuel economy, two-cycle engine ports should open much earlier when designed for high than for low speed, in order to more thoroughly get rid of the products of combustion. When it is discovered that the engine is being run at a speed in excess of that to which it is best adapted, the remedy is to make the ports open earlier, or hold the engine to slower speed by increasing the diameter, pitch, or blade surface of the propeller.

Should the engine, without missing explosions, begin to increase its speed, and then miss explosions and slow down, one would naturally be led to suppose the cause of the trouble to be insufficient length of contact of the sparking device as well as poor scavenging of the cylinder.

Trouble from loss of compression in the combustion chamber, whether in a two-cycle or a four-cycle engine, must be remedied before the engine can be made to run satisfactorily. If, in attempting to start, it is found that there is no compression, the valves should be examined to see if they seat properly and are timed correctly. Loss of compression may be caused by a leaky gasket, allowing the pressure to leak into the water-jacket, which is the first place to look for the cause of trouble after examining the valves. A leaky gasket may sometimes be discovered by noting whether or not pressure escaping into the water-jacket shows at the water discharge.

KNOCKING, OR POUNDING

9. Undoubtedly the sense of hearing is more useful in detecting irregularities in the running of an engine than any other sense. By means of the sounds produced, the engine talks to the operator, and with a little intelligent study he will soon understand the language. Even at a distance it is often possible to tell whether an engine is running regularly or whether, as indicated by the sound of the exhaust, some of the charges admitted to the cylinder are expelled without being exploded. Standing in close proximity to the engine, the operator may distinguish a variety of sounds indicating defects about the engine and calling attention to the necessity of applying proper remedies at the first opportunity.

A sharp, knocking sound in stationary engines may be due to any one of the following causes:

1. Lost motion in the bearings of the connecting-rod, either at the crankpin or the piston-pin end.

2. Lateral movement of a piston ring, the groove in the piston having become widened by wear.

3. A loose key in the flywheel or pulley.

4. Lost motion in the gears, causing the gear-shaft to be retarded in its revolution for a fraction of a second when the exhaust or inlet-valve cam hits the roller and lever.

5. Piston or cylinder worn to a considerable extent, causing an up-and-down movement of the piston.

6. The piston having worn a shoulder in the bore of the cylinder, and striking the shoulder if any play in the bearings is developed.

7. The piston striking any foreign body that may accidentally have been drawn into the cylinder.

10. Knocking in automobile engines may be due to looseness or rattle in some external part, owing to nuts having worked loose or to bolts being sheared off or being too small for their holes. Knocking due to such causes is readily detected by a careful inspection while the engine is running,

and this inspection may be aided by laying the hands on parts suspected of being loose, when vibration will easily be felt; also by careful scrutiny with an electric flashlight for evidences of movement where two parts are bolted together.

About the most likely place to find looseness of this description is in the holding-down bolts that hold the engine to the frame on which it is mounted; but in certain horizontal engines it may also be found that the caps over the main bearings are loose, owing to the fact that they have not been properly tongued into the bottom halves or pillow-blocks of the bearings. Looseness at either of these two points should be remedied at the repair shop, as it always necessitates the substitution of larger bolts, aided perhaps by dowel-pins; and in the case of the bearing cap it may be necessary to make a wholly new cap, with proper tongues fitting into grooves that must be machined or chiseled in the pillow-block.

11. A more probable cause of knocking is looseness due to wear in the main-shaft bearings, crankpin bearings, or the wristpin bearings. In a four-cylinder vertical engine, the main-shaft bearings may be quite loose without causing a knock, because the weight of the shaft and flywheel holds the shaft down; but a horizontal engine will, under certain conditions of speed and load, pound with a small amount of looseness. Only a very limited amount of looseness should be permitted in the main-shaft bearings of any engine, both on account of the danger of springing the shaft and because a bearing worn beyond this extent is liable to begin cutting, as it is difficult to keep sufficient oil in it.

12. Looseness in the flywheel bearing of a vertical motor is disclosed by putting a pry under the flywheel and working it gently up and down. In the case of a horizontal engine it is necessary to [illegible] the shaft approximately in line with the pressure of [illegible], and a lever will have to be applied to the flywheel or shaft in whatever manner seems most practicable. Occasionally looseness of the shaft

can be detected by rocking the flywheel back and forth against the compression in the cylinder. If the pull of the sprocket chain comes on the engine shaft, it may be possible to detect looseness in the adjacent bearing by alternately stretching and relaxing the chain, which can be done by grasping it midway between the sprockets and pulling it up and down as far as it will go.

Another very good way to disclose looseness in the main bearings of any car having a planetary transmission gear on an extension of the engine shaft is to tighten one of the friction bands of this gear by the appropriate lever, usually the low-speed or reverse lever. It is very rarely that the tension of these bands is exactly balanced, so as to impose no radial pull on the shaft, and tightening the band will move the shaft to whatever extent the adjacent bearing has worn.

A novice should not attempt to refit the main-shaft bearings, as this requires a good deal of skill and experience for its correct execution.

Wear in the crankpin bearings is disclosed by setting the cranks at about half stroke, and rocking the shaft back and forth.

13. Knocking in the wristpin, due to wear of the pin and its bushing, is not among the commoner troubles, and it does not need to be attended to at once unless aggravated. It is well, however, not to neglect it too long, as the bushings and the pin will be worn out of round, so that they cannot be used. A good engine will run a car several thousand miles before any replacement is demanded at this point. When it is taken out, the wristpin should be calipered all around. If it is out of round, it should be ground true; or, if this is impracticable, a new pin will have to be supplied, and the bushing reamed or scraped to fit. This, of course, should be done in a repair shop.

14. A cause of knocking occasionally found is due to the wristpin and the crankpin not being quite parallel. This causes the connecting-rod to oscillate from end to end of the

wristpin and crankpin bearings; and if, as is customary, there is $\frac{1}{16}$ or more of end movement in these bearings, the knocking may be quite noticeable. If, as is likely to be the case, it is impossible to make the pins parallel, the only recourse is to take up the lost motion at the end of one or the other bearing, and possibly both bearings, by the use of washers or cheeks soldered to one end of the bushing and brasses. This is not a common cause of knocking, particularly in the better class of engines.

15. The best construction is to secure flywheels to short shafts by bolting them to flanges instead of keying them. Sometimes, however, a flywheel is held on by a common key, or by two keys 90° apart, and frequently it will work loose on its keys. This will inevitably result in a knock, which will be very loud if the engine has less than four cylinders. The crank-case should be opened and the cranks blocked so that the shaft cannot turn, and then force should be applied to the flywheel to disclose the looseness, if any. Sometimes the flywheel will be so tight on its shaft as to resist turning in this manner by using any ordinary force. In this case, it is best to take the car to a repair shop if a thorough search has failed to disclose any other cause for the noise.

A sprung shaft will always cause knocking, and also rapid wear and cutting of the bearings.

16. Besides the foregoing mechanical causes of knocking, there is a class of what may be called *combustion knocks* that are altogether distinct from the preceding, in that they may occur without appreciable looseness in the bearings, and are due to excessive rapidity of combustion, coupled generally with too-early ignition, the charge being completely burned before the piston has reached the end of the compression stroke. Combustion knocks are due to a variety of causes, the most obvious of which is simply too-early ignition, as when running up a hill without suitably retarding the spark. A contributing cause is a slightly weak mixture, since such a mixture burns faster than a normal or

overrich mixture. Pounding in particular cylinders of a multicylinder engine may be due to unequal rapidity of combustion, which itself may be due to unequal charges, as when the valves are unequally timed, or to irregular spark timing, such as may result from a wabbling timer or badly adjusted vibrators. If the timer contact surfaces have been roughened by sparking or by wear, they will cause the contact maker of the timer to jump when running fast, and therefore to make erratic contact, resulting in irregular firing.

17. The classes of combustion knocks just mentioned are easily traced to their causes. The knocks are not necessarily violent, and they may sound a good deal like the knocks due to loose bearings, except that, if caused by faulty action of timer or vibrators, they will occur irregularly instead of regularly.

There is, however, another and very common sort of knocking due to spontaneous ignition of the charge before the spark occurs. This may be caused by overheating of the motor from lack of water or other trouble with the circulation—a trouble at once indicated by boiling of the water in the radiator or by smoking of the exterior of the motor. It is a temporary phenomenon, and involves no harm to the motor if the latter is promptly stopped and allowed to cool.

18. Much more troublesome, and also more common, is spontaneous ignition, or **preignition**, as it is termed, due to a deposit of carbon in the combustion chamber or on the piston head. A carbon deposit of this nature may be caused by too much gasoline or by too much cylinder oil, and it will accumulate gradually even with the carbureter and lubrication correctly regulated. A small quantity of carbon will give no trouble, but as the deposit thickens some portions of it will remain incandescent from one explosion to the next, and will ignite the fresh charge at some point in the compression stroke, depending on conditions. The fact that the charge is not ignited until some time during compression is due to the fact that the more highly it is

compressed, the more easily it ignites. True preignition results almost always, except at the highest engine speeds, in the charge being completely burned before expansion begins, and it is easily distinguished, especially if the engine is taking full charges, by the resulting sound, which is a sharp, metallic *bing! bing! bing!* closely resembling that produced by a hammer striking a block of cast iron. Usually, though not always, an engine that preignites in this manner will continue running by spontaneous ignition for some seconds after the igniter switch has been opened. The hammering due to preignition, as would be expected, is most marked when the engine is running slowly with the spark suitably retarded, and it will generally manifest itself when hill climbing, owing to the fact that the throttle is then wide open and the spark necessarily retarded to suit the slow speed of the motor.

19. In stationary engines, a heavy, pounding noise, such as is caused by premature ignition, may also be due to excessively high compression for the grade of fuel employed. In addition to its initial effect in producing a pounding noise, either preignition or a too-high compression pressure may cause the piston to expand unduly and to stick in the cylinder, which it would not do if the conditions were normal. This sticking of the piston would produce a knocking sound due to the small amount of play in the connecting-rod bearings necessary for smooth running.

A coughing or barking sound is caused by the escape of pressure past the piston, and would indicate the necessity either of replacing any worn or broken piston rings or of reboring the cylinder and fitting a new piston.

With marine engines, a loose coupling may cause a pound, as may also a loose propeller wheel, but these pounds can easily be located.

CYLINDER AND PISTON DISORDERS

20. Scored and Leaky Cylinders.—One cause of scoring of the cylinder lies in the fact that the ends of the piston pin or wristpin when loose sometimes protrude through the hole or bearing in the piston. Some pins have their bearing in the piston itself, while others, being tightly secured in the piston, have their bearing in the upper end of the connecting-rod. No matter which construction is employed, the ends of the pins should never come in contact with the cylinder walls. The pin must by some absolutely positive method be kept in place. While a loose wristpin is often the cause of a scored cylinder, there are three other causes, resulting from imperfections of design or of machine work, to which scoring can be traced; namely, loose core sand, imperfectly fitted piston rings, and loosening of the pins that are used to prevent the piston rings from turning in the slots in the piston.

21. Trouble from loose core sand is due to sharp sand that usually comes from the cored passage connecting the crank-case with the inlet or passover port to the combustion chamber of two-cycle engines. With cylinder castings properly pickled in dilute sulphuric acid to remove the sand, this trouble would not be experienced; but with modern methods of cleaning castings by means of the sand blast, the cored passages are frequently neglected. Some engines are provided with a removable plate over the inlet port, for the express purpose of making sure that there shall be no core sand therein to cause trouble.

If, in an engine of the two-cycle type, the scoring consists of several parallel marks on the side where the inlet port is located, it is safe to ascribe the trouble to sand. If the scoring is on the exhaust-port side, it is usually an indication of insufficient lubrication; as the hot exhaust gases pass out they burn the oil off that side of the piston and cylinder, the exhaust side of a two-cycle engine cylinder being always hotter than the inlet side. Scoring may occasionally be due to

the presence in the cylinder of pieces of the porcelain insulation of spark plugs. Cylinders have been practically ruined through dropping into the cylinder the pin or nut holding in place the spring on an inverted inlet valve.

22. Leaky cylinders—particularly in two-cycle engines—render the wristpin, crankpin, and main-shaft bearings subject to excessive wear, because the heat of the gases that pass by the rings into the crank-case tends to burn up the oil and heat the bearings. If the engine is of the two-cycle type, the leaking products of combustion not only foul the fresh charge of gas so that it is not so explosive, but the quantity of each charge is reduced.

If, in an engine in which the inlet and exhaust valves are tight and there is no leaky gasket, it is found that the compression has become materially reduced, the trouble is probably caused by leaks from distorted, scored, or imperfect cylinders, the pistons or piston rings being worn considerably or stuck in the slots in the piston. The only remedy is to remove the pistons for examination.

If the cylinder is found to be out of round or scored, it will have to be rebored, and new pistons and rings fitted. If the rings are found to be rusted or stuck in the slots, they will have to be removed, even if to do so it is necessary to break them. They may have worn to such an extent that the openings at the points of parting are such as to allow a loss of pressure, the leaking charge passing either into the tight crank-case, if the engine is two-cycle, or into the atmosphere. If such leakage is not stopped, the heat of the escaping gases will burn the oil out of the crank-case, and the bearings will soon become badly worn, if not ruined.

23. The piston should be examined carefully for wear. The side on which the angular pressure of the connecting-rod is exerted should, of course, show the most wear. If the front or rear side of the piston shows wear at top or bottom, with a corresponding amount of wear on the opposite bottom or top, it is proof that the hole through the piston for the piston pin, to which is connected the upper end

of the connecting-rod, is higher at the end showing wear at the top of the piston than at the end showing wear at the bottom. If this is found to be the case, and the wristpin is tightly secured in the piston, the connecting-rod bearing for the wristpin will be found to have worn badly and will be bell-mouthed, that is, larger at the ends than at the center. The remedy for this is to true up the hole carefully and bush it, or use a pin that is a trifle larger than the hole, increasing the size of hole in the upper bushing slightly. This is a repair job that should be entrusted only to a thoroughly reliable machinist having the tools and means for doing accurate work. Side wear on the piston is much more likely to show in engines having the wristpin held securely in the upper end of the connecting-rod, the ends of the pin having bearings in the piston.

24. Piston rings become stuck in the slots in the piston from two causes; namely, from water getting into the combustion chamber, causing the rings to rust, and from the sides of the slots being slightly tapered instead of parallel. Where tapered sides are found, it is usually necessary to straighten them up in a lathe and use slightly wider rings. Piston rings should be renewed much oftener than is customary. As they become more and more open at the ends, the hot gases passing by the ends of the rings have a harmful effect on the polished cylinder surfaces, and in two-cycle engines they foul the mixture in the crank-case.

25. Broken piston rings, particularly in engines with ports that are opened and closed by the pistons, are a source of annoyance, and frequently cause much trouble. Broken piston rings are frequently the result of insufficient care in putting the piston, with the rings in place, into the cylinder, but are more likely the result of getting a ring end caught in a port. To prevent this, two-cycle engine rings are usually pinned to prevent them from turning until the ends can get into the port.

The breaking of a piston ring is rather an unusual occurrence; it will cause loss of compression, that may be

distinguished from leakage due to the rings being worn by the fact that the broken ring will make a distinct clicking sound at the end of every stroke. It will also be found that oil squirted on the piston when a ring is broken will not stop the leak. If the engine has more than one cylinder, it is probable that loss of compression due to lack of oil would affect all the cylinders, whereas a broken ring affects one only. If a piston ring is broken, it becomes necessary to take off the cylinder without delay and put in a new ring.

26. Piston rings are supposed to be held in position by small pins, one in each ring, so that the joints of adjacent rings are diametrically opposite. If for any reason these pins break, a ring may slip round until its joint is in line with that of the next ring above or below. This will cause loss of compression that may be very puzzling; it is an unusual occurrence, and it may be necessary to take off the cylinder to locate the trouble.

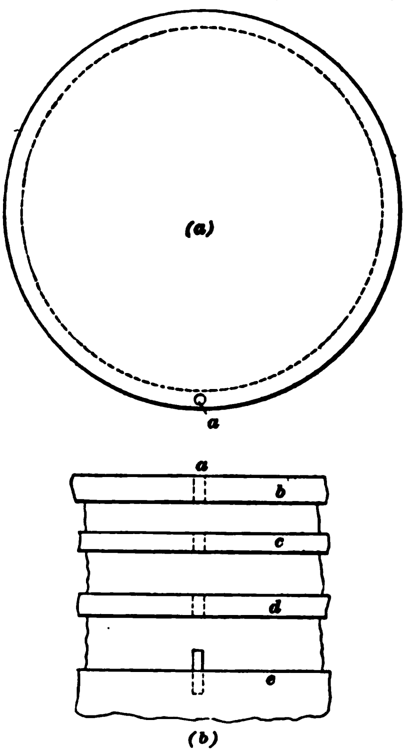


FIG. 1

27. A good method for pinning piston rings is shown in Fig. 1 (*a*) and (*b*). Fig. 1 (*a*) is a diagram of a piston head, the dotted lines showing the bottom of the ring slot, while Fig. 1 (*b*) is a sketch of a portion of one side of the piston. With the piston square on its lower end, drill, at *a*, a point about half way between the inlet and exhaust ports, through *b*, *c*, and *d*, a hole large enough for clearance for a

small tap, continue the hole into *e* with a tap drill, tap the hole, and screw into it a slotted screw to extend into the slot for a distance not quite one-half the width of the slot. Then tap and plug the hole through *b*, *c*, and *d* with screws dipped in muriatic acid to rust them in place, the screw plugs being in each case below the surface of the slot faces. At another point, where it would not come opposite a port, drill a hole through *b* and *c* and tap into *d*, plugging the clearance holes, as before. Drill at another point a hole through *b*, tapping into *c*. The slotted screws extend one-half or less the width of the slots from the bottom, so that, if the rings be parted as in Fig. 2 (*a*) one of the ends could be cut off slightly to receive the pin, or, if parted diagonally, as in Fig. 2 (*b*), a space could be cut out for the pin. With this method of pinning the rings, there is no way for the pins to work out to score the cylinders. While it is customary to pin the piston rings for two-cycle engines, pins are rarely found necessary in four-cycle engines, as such engines have no ports to catch the ends of the rings, except when an auxiliary exhaust is employed.


(*a*)


(*b*)

FIG. 2

28. Cylinder-Packing Troubles.—The joints between the cylinder head and the cylinder of stationary gas engines are kept tight by packings usually cut out of asbestos sheet about $\frac{1}{32}$ inch thick. When the packing is damaged by overheating or excessive pressure, water from the jacket leaks either to the outside or into the cylinder. The latter is the more serious leak of the two, as it interferes with the running of the engine by corroding the points of contact on the igniter and the valve seats and stems, and prevents proper lubrication of the piston and cylinder. Leaking toward the cylinder is generally indicated by splashing of the cooling water at the overflow pipe when the explosion takes place.

In most cases, the blowing out of a packing is caused by

the combustion pressure opening the joint between the packing surfaces, the packing being heated and partly destroyed, and allowing water to enter the combustion chamber. A partial or complete stoppage of the cooling-water supply or the clogging of the water spaces with lime or similar deposits will also result in the overheating of the cylinder and consequent damage to the packings.

As soon as a leak of water from a faulty packing develops, preparations should be made to renew the packing at the first opportunity. If the leak is to the outside, which may not interfere with the operation of the engine, although it will cause inconvenience through having to catch the water in buckets, it is not necessary to shut down the engine until the day's work is done. If the leak is toward the combustion chamber, the engine will generally stop in a short time.

29. Most automobile engines have the cylinder heads and cylinders in one piece; but a few engines have copper or aluminum water-jackets. There are, however, some old engines with separate heads still in service. In some cases, the cylinder heads, when separate, are made a ground fit on the cylinders, but they are commonly made tight by asbestos gaskets. Leakage through these may be detected sometimes by the sound, and sometimes by putting a little oil over the suspected place and noting the resulting bubbles when the crank is turned.

In case a cylinder-head gasket leaks, it will be necessary to put in a new gasket. The head should be taken off, the old gasket removed, and the iron surfaces in contact with it should be carefully scraped clean. The new gasket may be of sheet asbestos, and it should be sprinkled evenly with powdered graphite to prevent it from sticking. It may be cut to size by laying it on the cylinder and tapping it lightly with a small hammer to indicate the outlines. Care should be taken not to let inwardly projecting edges interfere with the valves or igniters; and, also, if there are openings through the head for the passage of water, it should be seen to that these are not closed by the asbestos.

A good packing for cylinder heads is sheet asbestos with woven brass wire embedded in it. This packing is much stronger than ordinary sheet asbestos, and will not blow out unless the cylinder-head bolts are loose or the head is a bad fit. In replacing a cylinder head, the bolts should be tightened gradually and evenly, each being tightened a little at a time, and the round being made three or four times, so as to avoid localizing the stress on any one bolt.

There is, of course, but one remedy for leaky gaskets, namely, renewal. The old gasket should be carefully and completely removed, and by means of a straightedge a careful examination should be made to discover, if possible, why the gasket gave way at a particular point. There may have been insufficient surface or too little holding-down pressure to keep the packing in place; the studs may have been too far apart at the point of rupture, or the nuts may not have been tightened after the engine had become heated.

VALVE DERANGEMENTS

30. Leaky Inlet and Exhaust Valves.—Trouble from loss of compression in the combustion chamber, when the spark plug is tight and there is plenty of oil on the piston, is generally due to leaky valves. In order to determine whether the leak is in the valves or in the piston rings, a moderate quantity of oil may be squirted through the compression relief cocks and the crank turned two or three times, which will temporarily check whatever leakage there may be around the piston. If the compressed charge still escapes, the inlet valve, if located over the exhaust valve, may be taken out and examined. The leak, however, is much more likely to be in the exhaust valve.

To take out the exhaust valve, turn the engine over by hand, with the switch off and the compression relief cocks open, until the valve is opened. Then prop up the valve spring with two pieces of wood or brass *a*, *a*, Fig. 3, cut to the proper length to go between the spring collar *b*, and the upper end (or lower end, if this is more convenient) of the

push-rod guide *c*, and turn the engine again until the push rod *d* is down as far as it will go. Push the exhaust valve down; the key at *e* may now be slipped out. If the props have been made accurately to length, the valve may be slipped up and out, leaving the spring and the collar in place. Inspection should show the valve seat to be of uniform appearance all the way around, and dull—not glossy. If the seat of either valve is pitted or rough, or if it is worn bright on one side, showing that it has been seating only on that side, it should be reground.

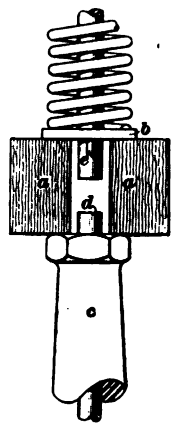


FIG. 8

31. The remedy for leaky valves is to regrind them to their seats. If badly scored and worn, which will be shown by a blackening of the seat and valve, it may become necessary to reseat and true up the valve, but if the engine has had ordinary care and attention, grinding should be sufficient. For this purpose, the exhaust valves may need emery and oil, finishing up with powdered oilstone, ground glass, silex, or the dirt that accumulates under a grindstone. The valve should not be rotated its whole circumference—as is frequently done, using a brace or breast drill with a bit screwdriver—but should be rotated a little, first in one direction and then in the opposite direction, raising it off the seat very often, and using oil freely, until a dull surface appears on both the valve and the seat throughout their bearing surfaces. Rotating the valve rapidly is very likely to cause grooves and ridges that are extremely hard to remove and make the valves tight.

While there is little or no danger of getting emery or other abrasive substance into the cylinder when grinding exhaust valves, ordinary care to avoid doing so should be exercised. The passage of the products of combustion being outwards, such matter would be carried away from the cylinder. Grinding the inlet valves is a very particular operation, for any particles of abrasive substance left behind

to be drawn into the cylinder are liable to cause trouble. All traces of grindstone dirt, which will be found well adapted for grinding and may be mixed with water instead of oil, should be wiped off carefully.

The valve stems should be inspected, and, if rusted or rough, should be cleaned and smoothed, a few drops of kerosene being applied to cut any deposits that may have accumulated in the guides.

32. Weak or Broken Inlet-Valve Spring.—Sometimes the inlet-valve spring, especially if the valve is of the automatic variety, will weaken from becoming overheated. This is almost sure to occur if the engine has been allowed to overheat from lack of water. In time a spring loaded too near its elastic limit will break from the jarring to which it is subjected. The symptoms in either case are loss of power at high speeds—although the power may still be ample at low speeds—and clattering of the valve and blowing back in the intake pipe at high speeds. The latter may easily be detected with a single- or double-cylinder engine by holding the fingers close to the air intake, when the backwards puffing will be very perceptible. If the engine has four cylinders, it may be possible for the inlet-valve springs to be slightly weak without the mixture blowing back at the intake, owing to the fact that one or another cylinder is aspirating all the time, and the air expelled from one cylinder is drawn into the next. One way to get around this difficulty is to block open the exhaust valves of two cylinders—the first and fourth or the second and third—while the others are tested. It will probably be simpler, however, to experiment with the valve-spring tension. If the valve spring is weak, and if it is temporarily increased in stiffness by putting washers under it to compress it, a marked increase in the power of the motor at high speeds will be observed. The proper remedy, however, is to put in a new spring, or, if this cannot be done, to stretch the old spring. For a valve lift of $\frac{1}{8}$ inch, and for average engine speeds, the tension should not be less than 1 pound

per ounce of the weight of the valve, washer, and key. The engine will work better if the springs are a little too stiff than if they are not stiff enough. There will also be less danger of breakage of the valve stems and keys.

33. Unequal Tension of Automatic Inlet-Valve Springs.—The effect of unequal tension in the springs of automatic inlet valves is to permit one cylinder to take more gas than another. Consequently, at slow speeds the cylinder whose valve spring is weak will get the larger charge; and at high speeds part of the charge will be blown back through the valve whose spring is weak, so that the other cylinders will get stronger impulses. A quick way to test the equality of valve-spring tension without taking out the valves is to run the engine slowly with the throttle almost closed. This will cause the cylinders whose springs are stiffer to receive scarcely any gas, and the cylinders whose valve springs are weak will do most of the work. It is possible, however, to go to excess in a test of this sort, since, when a motor is running light with the minimum quantity of gas, one cylinder is almost sure to get more gas than another, if the inlet valves are automatic, even with the most careful equalizing of the springs. If the tension of the valve springs is under suspicion, the valves should be taken out and the springs tested by compressing the valve stems together.

34. Excessive Lift of Automatic Inlet Valve.—The lift of an automatic inlet valve should be proportionate to the spring tension and to the weight of the valve, so that the spring will be able to overcome the inertia of the valve, and close it before the piston has started so far on its compression stroke as to expel any of the mixture through the open valve.

The symptoms of too great a valve lift are loss of power and blowing back at high speeds. A valve 2 inches in outer diameter should not ordinarily lift more than $\frac{1}{8}$ inch and a lift of $\frac{3}{16}$ inch would be excessive for almost any valves found on high-speed engines. An excessive lift, like a weak

spring, is likely to result in breakage of the valve stems and keys through unnecessary hammering of the valve when opening and closing.

35. Broken Inlet-Valve Stem or Key.—Trouble from a broken inlet-valve stem or key is more likely to occur with automatic valves than with those mechanically operated. The result, if the valve opens downwards, is to let it stay open all the time, causing that cylinder to cease work, while the sparks from the plug ignite the mixture in the intake pipe and cause explosions there and in the carbureter. If the valve, whether automatic or mechanically operated, opens upwards, it will clatter on its seat and permit much of the mixture to be expelled during the first part of the compression stroke.

36. Weak or Broken Exhaust-Valve Spring.—Owing to the heat to which it is subjected, the exhaust-valve spring is more likely to weaken than that of the inlet valve. The symptoms are loss of power, owing to the valve lingering open at the end of the exhaust stroke, and clattering when the valve closes.

37. Broken Exhaust-Valve Stem or Key.—As there is nothing to prevent the valve from being sucked wide open on the suction stroke, an accident of this kind will generally cause that cylinder to go out of action entirely. The clattering, if the engine continues running by virtue of other cylinders, is likely to be marked.

38. Slipped Valve Cams.—Some cheaply constructed motors have the valve cams held on the shaft by taper pins that in time shear partly or wholly through, permitting the cams to turn on the shaft. The cams may turn a short distance and then be jammed by fragments of the taper pins. The symptom indicating trouble due to this cause is partial or complete loss of power in the cylinder affected, when nothing is wrong with the ignition, valve-spring tension, etc.; and it will be equally marked at all speeds. If a cam is pinned

on its shaft, the proper way to secure it is to add another pin, or, better, to add a key to take the torsional stress, and depend on the pin only to keep the cam from slipping endwise on the shaft.

LUBRICATION TROUBLES

39. Lack of Cylinder Oil.—The symptoms of lack of cylinder oil are manifested in a sudden laboring of the engine, a dry or groaning sound, and partial loss of compression, followed by probable seizing of the piston. If the piston does not seize, it and the cylinder walls will at all events be scored.

Among the causes of lack of cylinder oil are clogging of lubricator by dirt or waste, obstruction in oil pipes, leaky check-valves, leaky pump packing, broken oil pipe, oil too cold to feed, lack of oil in crank-case, etc.

The remedies for trouble from this source will become obvious on inspection. The motor should be stopped and allowed to cool, and a liberal quantity of oil should be put in the crank-case before starting again. Squirt a little oil through the compression relief cocks to insure lubrication of the pistons, without waiting for oil to reach them from the regular sources. Remove the obstruction or repair the break as soon as possible.

40. Lack of Oil in Bearings.—A slightly loose main or crankpin bearing will sometimes be cut badly as a result of a temporary stoppage of oil feed, and yet give no noticeable symptom until the bearing is so badly cut that knocking begins. If a well-fitted bronze-bushed bearing becomes dry, it is more likely to stop or at least retard the engine. A babbitted bearing will melt out and let the shaft settle as far as other supports or bearings will allow. The result may be a violent pounding, a bent or broken shaft, or cut bearings generally, according to the particular conditions. There is no real safeguard against lack of oil in bearings except in the vigilance of the operator, combined with a system of oiling not liable to go wrong. It is not safe to depend

on detecting a dry bearing by the sense of touch, because often the metal adjacent to bearings is sufficient to carry the heat away.

Generally, trouble from this cause is due to neglect to supply oil or to see that the sight feeds are working properly. It may also be due to a broken pipe, cold oil, etc.

There is no excuse for neglect to clean the oil strainer, or failure to inspect the oil pipes, unions, etc., or to know when starting out how much oil is in the crank-case. A badly cut bearing should be sent to a repair shop, and should be attended to without delay; but a bearing only slightly cut may be kept in service by the addition of a small quantity of flake graphite to the oil. If possible, the shaft should be taken out and polished with emery cloth and oil, else bronze from the bearing is likely to cling to it and aggravate the cutting. A bearing supplied with oil from a well beneath it, and a chain running over the shaft, may occasionally fail to receive oil owing to the chain catching on some internal roughness or projection in the oil pocket. It is always safest to keep a more or less regular supply of oil passing through bearings of this sort when in use, and depend on the oil well only as an equalizer.

41. Improper Oil in Cylinders.—The trouble symptoms produced by the use of oil unsuited for lubricating the piston are white or yellow smoke in the exhaust, rapid fouling of spark plugs, partial clogging of inlet and exhaust valves, and rapid accumulation of carbon on the valves in the combustion chamber and about the piston rings.

To remedy the trouble empty out all the unsuitable oil if possible, and substitute oil known to be good. Inject kerosene freely through the compression relief cocks to loosen the carbon deposit on the piston rings, and use kerosene to free the valves if they stick. Drain the crank-case, and, if possible, open it and clean out any carbon that may have worked down past the piston and mingled with the oil. Change all the spark plugs, and clean them when opportunity offers. Put in plenty of fresh oil before starting, and see that oil is

supplied to the pistons so that they will not go dry before oil begins to feed from the cylinder lubricator.

42. Too Much Oil on Pistons.—Too much oil on the pistons is indicated by white smoke in the exhaust, fouled spark plugs and valves, substantially as when inferior oil is used, though the symptoms will not be so pronounced. An examination of the combustion chamber through the inlet valve or spark-plug hole, using a mirror and electric flash-light if necessary, will show an unnecessary amount of oil around the top of the piston. With the oil correctly regulated, it should not accumulate on the piston head in any great quantity.

Trouble from this source is remedied by drawing off part or all the oil from the crank-case, if it contains more than is necessary for running the engine, and reducing the oil feeds to the cylinders if necessary.

COOLING-SYSTEM TROUBLES

43. Lack of Water.—Lack of water in the radiator of the cooling system for automobile engines is indicated by the rapid emission of steam, if there is sufficient water to enter the engine jacket; the bottom of radiator being cold; the overheating and smoking of the engine, followed by laboring, groaning sounds, owing to the oil being burned away faster than it is supplied to the pistons; and, if the engine still continues running, expansion and seizure of the pistons in the cylinders.

Trouble from lack of water is due to carelessness in not filling the tank before starting; leakage in radiator or piping; accidental opening of the drain cock at the lowest point of the circulation system; breakage of drain cock by flying stone, etc.

The remedies for such trouble are apparent on inspection. If the motor becomes overheated so that the water boils rapidly away, and there is reason to think that the upper portion of the water-jacket is dry, the motor should be

allowed to cool before water is added; otherwise, the sudden contraction may warp or even crack the cylinders, or it may cause the cylinders to contract and seize the pistons. If the water gives out when at some distance from the nearest source of supply, the motor may be allowed to cool off and the car then run with throttle nearly closed, and the spark advanced as much as it will bear without knocking. This may be kept up sometimes for $\frac{1}{2}$ mile before it is necessary to stop to cool the motor. The crank-case should be liberally supplied with oil to prevent the pistons from becoming dry, or, if a sight-feed oil cup is put on the cylinder, it should be set to feed quite rapidly. The motor should be stopped at the first sign of distress, as indicated by a groaning sound, turning with difficulty, or knocking caused by preignition due to hot cylinders.

44. Obstructed Circulation.—An obstruction to the circulation of the cooling water elsewhere than in the radiator will cause the bottom of the radiator to remain cool while the top is, probably, boiling hot.

Among the causes of obstructed circulation are a broken pump, broken driving connection to pump, or slipping belt or friction pulley, if the pump is driven in that manner; waste or the like lodged in the pump or piping.

The remedies for this trouble will become obvious on inspection. If the belt or friction pulley has oil on it, gasoline may be used to clean the pulley, as well as the flywheel if it drives the pulley.

45. Scale or Sediment in Radiator.—The presence of scale or sediment in the radiator is indicated when the whole radiator becomes hot or when steam formed in the jacket forces water out of the upper pipe to the radiator, there being no oil on the inside or dirt on the outside of the radiator.

Scale will deposit from hard water if the temperature of the water is allowed to approach the boiling point. A similar scale, almost impossible to eliminate, will crystallize

from calcium-chloride non-freezing mixtures if these are allowed to become supersaturated.

A radiator badly choked with lime scale is practically hopeless, although, if it is made entirely of brass and copper, it may sometimes be helped by the use of a dilute solution of hydrochloric acid in the proportion of about one of acid to ten of water. This should be left in the radiator long enough only to loosen the scale, and should then be drawn off, and the radiator washed out. It is better in doing this to disconnect the radiator from the engine, in order to confine the effects of the acid. Another method is to use washing soda, as explained in *Automobile and Marine Engine Auxiliaries.* Ordinary dirt may be cleaned out by a strong, hot solution of lye, which should be used with care, as it burns the skin badly. Rainwater should be used wherever possible, and all the water should be strained.

46. Dirty Radiator.—When the whole radiator is hot and it is impossible to run in low gear without boiling the water, the circulation being good, it is evident that the radiator is dirty.

Flying oil about the motor may lodge on the air surfaces of the radiator tubes, and gather dust, which forms a non-conducting covering. Oil sometimes gathers on the water surfaces by gradual escape from the pump bearings, or may remain after an attempt to substitute refrigerator oil for water as a cooling medium in freezing weather. The film of oil, preventing the water from coming in contact with the metal, acts practically as an insulator.

To remove the oil from the radiator use kerosene, or a mixture of kerosene and mineral-oil soap. Dissolve the soap in water and add it to the kerosene, fill up the radiator with the mixture, and run the car for an hour or more until the radiator gets well heated. The soap and kerosene will form an emulsion with the oil, and when the mixture is hot it may be drawn off and the radiator washed out with cold water. For the removal of the external oil and dirt, use gasoline, with a brush or swab.

A simple trouble, but one likely to be mistaken by the novice for radiator or circulation trouble, is slipping of the fan belt. The belt should be tested occasionally, and not allowed to get so loose that the fan pulley can spin inside it. It does not need to be tight.

CARBURETER DISTURBANCES

PROPORTIONING OF MIXTURE

47. Overrich Mixture.—If a mixture is very rich, that is, if there is an excessive amount of gasoline in the charge, the fact will be manifested by black smoke in the exhaust. If the mixture is not rich enough to produce smoke, it will still produce an acrid odor in the exhaust, and will cause overheating of the radiator, unnecessary sooting of the plugs, accumulation of carbon in the combustion chamber, and unnecessarily rapid comsumption of gasoline, with diminished power. An automobile of from 12 to 20 horsepower, running at an average speed of 20 miles an hour, on good and fairly level roads, should be able to cover 20 miles on a consumption of a United States gallon of gasoline. If it does not do this, the carbureter is incorrectly adjusted or is inefficient.

The causes of an overrich mixture are: faulty carbureter adjustment; leaky float; leaky float valves; float too high on its stem or too heavy; spray nozzle loosened or unscrewed by vibration; and dirt on the wire-gauze screen over the mouth of the air-intake pipe.

For float troubles, see Arts. **52** to **55**, inclusive. Dirt over the intake may have gathered gradually or it may have been splashed on from a muddy road. Its effect is to increase the suction in the spray chamber and to diminish the air taken in. If necessary, a shield should be fitted to prevent mud from reaching the air intake and carbureter. If the float is in good order, the carbureter will probably need readjustment.

48. Flooding is the most common source of trouble in marine engines using vaporizers. It is caused by leakage of gasoline into the vaporizer, from which in a two-cycle engine it readily runs into the crank-chamber; the resulting mixture is too rich in gasoline, and, not having sufficient oxygen, is unexplosive. When trouble from flooding is suspected, turn the engine over two or three times, with the gasoline valve and the switch closed. If there is an explosion, note the color of the flame at the relief cock, or priming cup, which should be left open for the purpose. If no explosion occurs, leave the cock or cup open and slowly turn the flywheel to a point just before the exhaust port opens, thus drawing air into the cylinder through the priming cup to dilute what is thought to be an overrich mixture. Now revolve the flywheel in the opposite direction rather rapidly until the spark occurs. If there is no explosion, try again, and repeat the operation two or three times if necessary. If an explosion then takes place, it is evident that flooding is present.

To remedy this in a two-cycle engine, open the draw-off, or drain cock in the lowest part of the crank-case, and draw off the contents, taking care, however, to replace with a fresh supply the lubricating oil thus drawn out. If there is no draw-off cock, it will be necessary to turn the flywheel many times to exhaust the excess of gasoline in the crank-case, leaving the switch closed and the compression relieved as much as possible. After a while, an explosion should take place, then another, gradually becoming more frequent, until finally the engine may run with an explosion at every other revolution or so. The gasoline valve should be kept closed until the charges explode regularly and the red tinge to the flame at the relief cock and smoky exhaust disappear, after which the gasoline may be turned on and regulated at the needle valve in the vaporizer, closing it slightly at first; and, if the engine slows down somewhat, open it slightly until it is possible to tell whether it is getting too little or too much gasoline.

In case of flooding in a four-cycle engine using a vapori-

zer, two or three revolutions of the crank-shaft will usually dispose of any excess of gasoline, for there cannot be as large an amount in the exhaust piping of a four-cycle engine as could accumulate in the crank-case of a two-cycle engine. Trouble from flooding in a two-cycle engine is the first thing to be suspected when an engine of that type refuses to start readily.

If the cause of a failure to start is found to be an insufficient supply of gasoline, due to dirt in the needle valve, or to a small amount of water in the gasoline piping, lift the valve in the vaporizer from its seat and let a little gasoline run through to clear the obstruction or get a drop or two of the water out, being sure to catch the drip for examination. If there is any water it will show in globular form at the bottom of the vessel. In case water is found, the pipe must be disconnected and drained, and any water in the tank must, if possible, be removed, for a single drop of water will completely close the aperture in the seat of a needle valve.

49. Weak Mixture.—Among the symptoms produced by a weak mixture are insufficient power, although the explosions are regular; a tendency to preignite or to burn very rapidly if there is the slightest carbon deposit; the engine sometimes will miss every other explosion. There is likely also to be difficulty in starting the engine. It is not always easy to distinguish between lack of power due to an overrich mixture and that due to a weak mixture, but the tendency of the former is to produce black smoke and of the latter to preignite and miss explosions. Some experimenting with the carbureter adjustment will often be necessary to settle the point.

Nearly all the causes named in Art. **47** will make a mixture richer at some speeds than at others, and if the carbureter has been readjusted, for example, in the attempt to correct trouble due in reality to a heavy float, the result will be to make the mixture faulty again at certain other speeds. Special causes of weak mixture are dirt or waste in the

gasoline pipe or strainer; stale gasoline; carbureter too cold to vaporize; dirt in the spray nozzle; float too light or too low on its stem.

For float-trouble remedies see Arts. **52** to **55**, inclusive. Experimenting with the carbureter adjustment should be very cautiously done, with the original setting or adjustment marked so that it can be restored if necessary. The carbureter should then be adjusted slightly in one direction or the other, and the effect noted before further change is made. Very often a combination of adjustments will be necessary, but it is best to make them one at a time. If a radical change is made, it may be very difficult to start the motor at all, and this would leave the experimenter completely in the dark as to what was required.

DIRT IN CARBURETER AND GASOLINE PIPING

50. Dirt in Carbureter.—If there is dirt in the float valve, it will prevent the latter from closing and will cause the carbureter to flood. This will produce an overrich mixture, especially at low speeds, and is highly dangerous on account of the liability to fire. If the dirt is in the spray nozzle, it will produce a weak mixture. If the dirt has been splashed into the air intake, it will produce an overrich mixture, especially at high speeds.

The remedies for trouble due to dirt in the carbureter will become obvious when the nature of the trouble is located. A carbureter that has previously worked well and that suddenly begins to leak has in all probability dirt in the float valve. A carbureter that suddenly gives a very weak mixture has dirt probably in the gasoline pipe, strainer, or spray nozzle.

51. Dirt or Waste in Gasoline Pipe.—It is a common practice to carry a bunch of waste under the seat of an automobile. Usually, the gasoline tank is near the seat, and in time a sufficient quantity of fluff from the waste may enter through the vent-hole in the feed-cap of the tank to create

an appreciable obstruction in the gasoline pipe. Even if this does not happen, dirt or other obstructions sometimes accumulate, especially if the gasoline has not been properly strained. The symptom is a sudden or gradual weakness of the mixture, necessitating readjustment of the carbureter in order to keep the engine running. The most probable place of lodgment for obstructions of this sort is in the gasoline pipe where the latter connects to the carbureter, or at the strainer, through which the gasoline generally passes just before it enters the float chamber. Disconnecting the gasoline pipe or the union exposing this strainer will generally disclose the obstruction. Sometimes it may be necessary to disconnect the gasoline pipe at both ends, and blow it out with the tire pump. This is necessary only when the pipe has been disconnected near the carbureter and gasoline does not flow freely from it when turned on at the tank.

FLOAT TROUBLES

52. Leaky Float Valve.—With a leaky float, the carbureter drips when the main gasoline valve is opened. The leakage is not stopped when the top of the float chamber is opened and the needle valve pressed down with the finger, or when the mixing chamber is opened and the spray nozzle covered with the finger.

To remedy the trouble grind in the valve with pumice or fine sandstone.

53. Float Too High.—By the expression *float too high* is meant that the float is set too high on its stem so that it is not lifted by the gasoline sufficiently to close the float valve before gasoline escapes from the spray nozzle.

When this trouble is present, the carbureter drips when the main gasoline valve is opened; but the float valve is soon closed by the float if the spray orifice is covered by the finger. The float valve closes tight when manipulated by the fingers, or when the float is lifted by a pair of bent wires. When the trouble is due to a high float, it will be found that the

float itself is empty, and, if of cork, that it is not gasoline-soaked.

Unless the float is adjustable on its stem, the easiest remedy for this trouble is to bend the levers by which the float acts on the float valve. If this cannot be done, shift the float $\frac{1}{16}$ inch lower on the stem by the use of a soldering iron.

54. Float Too Heavy.—The same symptoms are present when the float is too heavy as when the float is too high, but they are caused generally by a leak in the float or by its being gasoline-soaked.

If the float is hollow, it will sometimes be found that there is present in it a minute leak due generally to some oversight in soldering. If the float is taken out and shaken with the hand, the presence of the gasoline inside of it will at once be apparent. The float should be immersed in warm water until all the gasoline in it is slowly boiled away and its vapor has been expelled through the aperture in the float. By holding the float under water, the escape of bubbles will indicate this aperture. Care should be taken that the vapor escaping from the float does not cause fire. When the leak has been located it should be marked with a pencil, and after the float has become cold the leak may be closed with a minute drop of solder. If the float is of cork, it may be saturated with gasoline. It should be taken out, allowed to dry slowly, and given a coat of shellac, care being taken that the shellac enters all the holes on the surface.

55. Float Too Light or Adjusted Too Low.—By the expressions *float too light* or *adjusted too low* is meant that the float is lifted by the gasoline in the float chamber when the gasoline level is still some distance below the orifice of the spray nozzle.

Among the symptoms produced by a light float or a low adjustment are a weak mixture at slow speed, and, probably, difficulty in starting the engine, owing to the fact that considerable suction is required to lift the gasoline to the mouth of the spray nozzle. The height of the gasoline in the spray

nozzle can generally be determined, with the aid of an electric flashlight, by a little experimenting with the float, pushing the latter down for an instant after it has closed the valve.

To remedy the trouble, the float must be weighted slightly, so that the gasoline will rise higher before the float closes its valve. The weight may take the form of a few drops of solder carefully distributed over the float so as not to overbalance it on one side; or, if this is not sufficient, a ring of sheet brass may be soldered to the top of the float.

FUEL TROUBLES

56. Stale Gasoline.—If an automobile has been left standing for some time unused, more or less of the gasoline in the tank will evaporate, and it may get too stale to give a correct mixture without readjustment of the carbureter. The usual symptoms are difficulty in starting the engine, and insufficient power owing to a weak mixture. The best remedy is simply to fill up the tank, when the mixture of old and fresh liquid will probably work satisfactorily. It may be necessary, however, to readjust the carbureter or to throw away the stale fuel. It frequently happens when touring that the gasoline procured at country stores is very stale, and it is safest to test it with a hydrometer before accepting it. The user should know for what density his carbureter is adjusted, and should not depart from this more than is necessary. Ordinary stove gasoline is supposed to test 74° or 76° Baumé, but is frequently found testing as low as 68° or 66°.

57. Water in Gasoline.—Water may be found in gasoline taken from a barrel standing out of doors. The water, being heavier than the gasoline, will always settle to the bottom, and by close observation it may be seen before it is poured into the tank. If the gasoline is strained through a piece of chamois skin or several layers of cheese cloth, or even through very fine brass-wire gauze, the strainer will hold the water while permitting the gasoline to pass through.

The user should make it an invariable rule to strain his gasoline in this manner.

The symptom of water in the gasoline will be immediate stoppage of the engine when the water reaches the spray nozzle, in spite of the fact that the timer, coils, battery, spark plugs, etc., are in perfect order, and the gasoline tank is known not to be empty. The only remedy is to unscrew the wash-out plug at the bottom of the carbureter, and let the water and gasoline run out until it is certain that all the water has escaped. Sometimes it may be necessary to disconnect the gasoline pipe entirely and blow it out in order to expel the last drop of water. It is well also to look into the tank with an electric flashlight and see if any drops of water can be discovered on the bottom. If so, it may be well to drain the entire tank. Extreme care should be taken to avoid fire while gasoline is being run off.

58. In stationary practice, besides using gasoline of proper quality, it is of course supposed that the storage tank contains a sufficient quantity of fuel to run the engine. This appears to be a superfluous precaution, nevertheless it has frequently happened that an expert has been sent several hundred miles, on complaint from the purchaser of an engine that he was unable to start it, only to find that there was no gasoline in the tank. In other cases it was discovered that, instead of gasoline, almost pure water was pumped to the engine. The explanation was that fuel purchased from a local dealer contained a considerable quantity of water, which of course settled to the bottom of the tank, and accumulated gradually until with the tank about one-quarter filled, nothing but water would be delivered to the engine. To avoid this, the contents of the tank should be examined at regular intervals or when the supply is low, and the tank drained whenever there is any doubt about the quality of the liquid that settles in the lower portions.

BACK FIRING

59. The cause of back firing in stationary engines is in most cases due to the delayed combustion of a weak mixture containing an insufficient amount of fuel. The result of such a mixture is a weak explosion and slow burning, so that, during the entire exhaust stroke and even at the beginning of the suction stroke, there is a flame in the combustion chamber. The fresh charge will therefore be ignited by the flame of the delayed combustion of the previous charge; and, as the inlet valve is open at that time toward the air-supply pipe or passage, a loud report will be heard in the air vessel or in the space under the engine bed whence the air is taken. The remedy for this condition is to increase the fuel supply until the explosions become of normal strength and the back firing ceases.

Another cause of back firing may be the presence of an incandescent body in the combustion chamber, such as a sharp point or edge of metal, a projecting piece of asbestos packing, soot, or carbonized oil, and similar impurities accumulating in the cylinder. To stop back firing from these causes, any projections of metal or other material should be removed with a suitable tool, and the walls of the combustion chamber made as smooth as possible, or the cylinder should be cleared of any deposit of soot or carbonized oil that may have gathered there.

Failure of the igniter to fire all charges admitted to the cylinder, or improper composition of the mixture resulting in the same way, will be indicated by heavy reports at the end of the exhaust pipe. One or more charges may in this manner be forced through the cylinder into the exhaust pipe, and the first hot exhaust resulting from the combustion of a charge will fire the mixture that has accumulated in the pipe and the explosion will be accompanied by a report similar to that of the firing of a heavy cannon.

60. On account of the shorter time between the opening of the exhaust port and the admission of the new charge in

a two-cycle engine, there is much greater liability to back firing in an engine of that type than in a four-cycle engine. In a four-cycle engine back firing will occur only when the inlet valve is off its seat; hence, in marine practice, back firing is more of an element of danger in four-cycle than in two-cycle engines. If there is no check-valve in the carbureter or vaporizer, and there is no direct opening to the atmosphere, the column of flame that would be blown into a boat through a carbureter or auxiliary air supply on account of back firing would be particularly dangerous because accumulations of gasoline vapor, especially in cabin boats, might thereby become ignited.

To be absolutely safe, a marine four-cycle engine having a float-feed carbureter not supplied with a check-valve should take its supply of air from some point outside of the cabin or from the top of the engine, rather than from a point near the base. As the use of a check-valve in the carbureter would materially reduce the efficiency of the engine, it is rarely used. If a float-feed carbureter is used, and indications point to imperfect carburization, the carbureter should be examined carefully. If the float leaks, so that the height of gasoline is constantly above the desired level, or if the float does not cut off the supply where it should, it will be necessary to take the carbureter apart to ascertain the trouble, which may be due to a stopped-up needle valve or nozzle.

61. Explosions in the muffler and exhaust piping are usually caused by the ignition of the gas accumulating from missed explosions due to weak mixtures or faulty ignition. They are not usually dangerous unless the muffler is large and is weakened by rusting inside or out, as from salt water passing through it or from damp salt air, against which it seems almost impossible to protect it in a boat.

62. Explosions in the carbureter are sometimes caused by the inlet valve sticking open and permitting the flame to communicate from the spark. More often it is due to improper mixture, which burns so slowly that flame lingers

in the cylinder even after the exhaust stroke is completed and the inlet valve begins to open. Either a weak or a rich mixture will produce this result, though not always both in the same engine. Carbureter explosions are often attributed to the exhaust valve closing after the inlet valve opens, or to simple leakage of the inlet valve; but these are seldom the real causes.

IGNITION TROUBLES

PREIGNITION

63. Definition.—Premature ignition, or preignition, while somewhat similar to back firing in its nature and origin, manifests itself in a different way and has a different effect on the action of the engine. Premature ignition, as usually understood, is the firing of the partly compressed mixture before the time fixed by the igniting mechanism. Its causes are similar to those that result in back firing, the effect being different in that the charge is ignited later than when back firing takes place, but before the end of the compression stroke. Preignition will cause the engine to lose power on account of the maximum pressure being exerted on the crank before it reaches the inner dead center and thus having a tendency to turn it in the wrong direction, against the momentum of the flywheels.

64. Causes of Preignition.—Besides the causes cited in connection with back firing, preignition may be due to any one of the following defects: Insufficient cooling of the cylinder, due either to shortage of cooling water or to the fact that portions of the water-jacket become filled with lime deposits or impurities contained in the water, thus interfering with proper circulation; compression too high for the grade of fuel used; imperfections in the surfaces of the piston end or valve heads exposed to the combustion, such as sandholes or similar cavities in which a small portion of the burning charge may be confined; electrodes or

other parts of the engine exposed to the burning charge too light; or the piston head or exhaust-valve poppet insufficiently cooled and becoming red hot while the engine is running under a fairly heavy load.

65. Premature ignition manifests itself by a pounding in the cylinder, and, if permitted to continue, a drop in speed, finally resulting in the stopping of the engine. It will also put an excessive amount of pressure on the bearings, especially the connecting-rod brasses, and cause them to run hot even when properly lubricated. After a shut-down due to premature ignition and a short period during which the engine is idle, allowing the overheated parts to cool off, it is possible to start again without difficulty and run smoothly until the conditions of load will cause a repetition of the trouble.

66. The remedies to be applied, according to the source of the difficulty, are as follows: Increase the water supply until the cooling water leaves the cylinder at a reasonable temperature, which may vary with the fuel used, but which should never be over 180° F. Clean the water space and ports of any dirt or deposit so as to insure free circulation of the cooling water. Reduce the compression by partly throttling the air and fuel supply. Plug any sandholes or blowholes in the piston or valve heads, and make these surfaces perfectly smooth. Replace electrodes or other light parts with more substantial ones, capable of absorbing and carrying off the heat without becoming red hot. If necessary, arrange for cooling the piston by blowing air into the open end of the cylinder.

If the head of the exhaust valve becomes too hot, it is a sign that it is not heavy enough, and it should be replaced by one with a head of sufficient thickness to carry off through the valve stem the heat imparted to it by the combustion. If a small particle of dirt lodges in a remote portion of the combustion chamber, the richer part of the charge may not reach it until the piston has traveled over a considerable portion of the compression stroke, and the

resulting **self-ignition** may properly be called preignition. It is advisable, therefore, to examine thoroughly every part of the combustion chamber and remove any dirt that may have lodged there.

67. Preignition in automobile engines is indicated by early ignition with a retarded spark. Usually, the engine will continue running for several seconds after the switch has been opened. The knock due to preignition has a sharp, metallic ring, easily distinguishable from other knocks in the engine. Even if ignition is not actually started by hot carbon or other cause, the first increase in pressure after the spark occurs may produce spontaneous ignition of the mixture near the heated object, so that the charge burns from two or more points at once, thus spreading the flame far more rapidly than usual.

If the engine has two or more cylinders, and only some of them incline to preignition, the result is that it is impossible to time the ignition correctly for all cylinders. The cylinders having a tendency to preignition must receive a late spark to prevent combustion from being completed too early, while the other cylinders will require an early spark. It follows from this that it is impossible to get the engine to develop its full **torque,** or turning moment, unless it is running so fast that the tendency to preignition may be neglected. As the effect of preignition is to cause combustion to be completed before expansion has begun, it is dangerous to run the engine slowly, and this is true even if only one cylinder is preigniting. If the engine is running at good speed, with an early spark, the symptoms will be those of rapid combustion in the cylinders affected; namely, a hardness in the sound of the explosion, without actual knocking, while in the other cylinders, if any, the explosion will be soft. As the speed of the engine is reduced, and the spark retarded to suit, the hard sound of the explosions gives place to unmistakable knocking. A good test for preignition due to carbon is to start the motor with everything cold, and run the car smartly up the nearest hill before the water in the

radiator has had time to get hot. The *bing! bing! bing!* then is a sure sign. If the carbon deposit is very great, the motor may knock when gearing up, if this is done quickly with the motor running rather slowly.

In automobile as in stationary engines, preignition is brought about by incandescent carbon deposits in the combustion chamber, on piston head, or on valves, or by bits of loose carbon left after scraping out, etc. It is sometimes due to small, accidental projections on the inner wall of the combustion chamber or head, due to defects in casting. If these are located in the path of the hot gases, it will take very little carbon deposit on them to overheat. Preignition is also caused by lack of water, resulting in general overheating.

It must not be supposed that all carbon deposits are due to neglect. Even the most scrupulous regulation of the best possible oil, and even the most efficient carbureter, will not wholly prevent a gradual accumulation of carbon, but it ought not to become troublesome in less than a season or two. A high-compression engine will, other things being equal, preignite sooner than one with low compression.

The only remedy for carbon deposit that amounts to anything is to scrape it out. To do this it may be necessary to take off the cylinders, but it may also be done in some cases by the use of special forms of scrapers that will reach into the combustion chamber through the inlet-valve or spark-plug hole.

If it is impracticable to scrape the cylinders at once, the trouble may be evaded after a fashion by running throttled and by running on a lower gear at the first symptoms of a pound. Increasing the richness of the mixture will also prevent pounding by making the charges burn more slowly, but this brings its penalty by adding to the carbon already present. If this trouble is due to chance projections in the combustion chamber, these may generally be disclosed by an electric lamp and mirror and when the cylinders are taken off, the projections can be cut away with a cold chisel.

BATTERY TROUBLES

68. Weak Battery.—Missed explosions may result from a weak battery. An open-air test of the spark, by disconnecting a cable from one of the plugs or laying a screwdriver on the plug binding post, will show a weak spark when the battery is weak. It is sometimes difficult to determine whether the explosions are missed because the battery is weak or because of a loose connection or broken wire somewhere in the ignition circuits. The only reliable way to determine this point, unless one has a fresh set of cells in reserve, is to carry a battery tester and test the cells as soon as skipping occurs. The battery strength required will depend on the character of the coil, but it is not often that a dry cell showing less than 5 amperes on short circuit is worth retaining.

If both sets of dry batteries are so far exhausted that neither will work the coil, the two may be coupled in series, which will generally make it possible to run the car for some miles farther. When home is reached the batteries should be recharged or replaced.

A wet- or a dry-cell battery for supplying the current will be exhausted after a certain period of time, and, if handled carelessly, its life may fall far below what may reasonably be expected. If a wet battery becomes exhausted through long service or accidental short circuit in its parts or connections, the contents of the jars must be emptied and the charge renewed. The manufacturer or dealer in electrical supplies furnishes full printed instructions with every set of renewals for batteries. It is generally false economy to try to use part of the old charge. In almost every case it is far better to throw away all of the original zincs, oxide plates, and solution, rather than to try to rejuvenate the cell by adding to or replacing part of its contents.

69. Current Leakage.—Sufficient leakage of current to make trouble—but not enough to be observed without testing with a magneto—may be due to moisture in the mica insulation of the insulated electrode or to a bridge of carbon.

When it is suspected that the trouble is due to either of these causes, it is a good plan to dry out the insulation thoroughly and clean the lower end with a brush or piece of waste and a little gasoline.

These troubles are more liable to occur when the batteries have become weak from use, or so far exhausted that they will not give sufficient current for ignition.

70. Testing Batteries.—By using a small electrical buzzer or bell each cell may be tested separately, and by the tone or sound it can readily be observed whether or not the battery needs renewing, as is often the case. A small pocket ammeter or voltmeter is very convenient for the purpose of testing batteries, but each cell should be tested separately, as the pocket apparatus will rarely stand the voltage or amperage of more than one cell. Occasionally the buzzer, bell, or voltmeter will show one of the cells of the battery exhausted or dead, and on its removal the battery will show sufficient strength for ignition purposes.

71. Reserve Battery Power.—While four or five dry cells, when new, will furnish sufficient current for ignition, it is customary to install six or even eight cells, so that, when they become partially exhausted, or it becomes necessary to remove one or two from the circuit, there will be a sufficient number left to supply the necessary current. It is, however, never safe to depend on a single battery. A reserve set of dry cells, carefully wired up, should always be carried in a dry box, for frequently when used in a boat the bottoms of the dry cells may become damp or the switch is liable to be left closed, with the electrodes in contact, with the result that, through the short circuit thereby produced, the battery will be exhausted and ruined in a very short time.

SPARK-PLUG DISORDERS

72. Broken Spark-Plug Porcelain.—The breaking of a spark-plug porcelain usually results in complete failure to ignite the charge in that particular cylinder, or

the secondary current **shorting,** that is, short-circuiting, through the break. The outer end of the porcelain will generally be loose when tried by the fingers.

The usual cause of breaking is screwing the bushing down too tight. If the asbestos packing is of uneven thickness, it may be necessary to screw the bushing quite tight to prevent leakage. Overheating and splashing of water on a hot porcelain will also cause breaking. Remedies for such trouble are found in using new asbestos packing and in providing protection from water, etc.

73. Soot on Spark-Plug Porcelain.—Soot on the spark-plug porcelain will cause misfiring, or total failure to ignite, when the battery is of proper strength and the vibrators on the coils are working properly. If the engine has more than one cylinder, probably one or more will be found to be working properly, and the one with the defective spark plug may be located by holding down one coil vibrator after another, thus stopping explosions in each cylinder in turn, until the vibrator feeding the inactive cylinder is reached. By listening carefully to the exhaust, when it is known that one cylinder is misfiring, it will be observed that, when the vibrator of an active cylinder is depressed, it will cause a noticeable break in the cycle of explosions. When the vibrator of an inactive cylinder is depressed, no such break will be noticed. It is, of course, necessary to know which cylinder is fed by each vibrator. A spark plug may be sooted to the extent of short-circuiting when in the cylinder, and yet spark properly in the open air, as the electrical resistance of air increases greatly when the air is compressed. If a plug is slightly sooted, and there is uncertainty as to whether the trouble is due to the soot or to something else, insert a fresh plug, substituting one from another cylinder, if there are no spare plugs at hand, and note the result. A primary sparker coated with soot will act nearly the same as a sooted plug; the extra current producing the spark will leak away to a considerable extent through the carbon instead of producing an effective spark.

The causes of sooting are too much lubricating oil, inferior oil, or a too-rich mixture. The overrich mixture will deposit pure black soot, whereas an excessive quantity of lubricating oil will produce a rusty-brown deposit. Inferior oil may produce almost any sort of a deposit, according to its quality. A great excess of either good or bad oil will not burn completely before it reaches the plug, and will deposit on the latter a greasy mixture of carbon, tar, and oil. An engine receiving oil in such quantities as this will foul the plugs within a mile or two, and energetic measures must be taken to get rid of the surplus oil.

If the sooting is not excessive, and if the cause is removed, the plug may be kept in action without cleaning by the use of an auxiliary spark-gap device, which may be connected to the binding post of the plug. The soot will then be gradually burned off.

74. Leaky Spark Plug.—If the leak is between the plug shell and the cylinder, it will be denoted by the hiss of escaping gas on the compression and power strokes. The plug may be screwed tighter or a new gasket used. If the leak is through or past the packing inside the plug, the same hiss will be heard, and in addition the outer end of the porcelain will show traces of soot after the gases have been leaking for some time. If the bushing of the plug has been screwed as tight as is prudent, with regard to the safety of the porcelain, it will be necessary to repack the plug. A plug allowed to leak to any noticeable extent will overheat, cracking the porcelain or burning the screw threads.

MAKE-AND-BREAK IGNITER TROUBLES

75. Poor Contacts.—In order to obtain a spark of sufficient size in the combustion chambers of engines equipped with the make-and-break system of ignition, it is necessary that a good contact be made between the two electrodes of the igniter plug before they separate. The current passes through the bearing of the movable electrode, and, if the

contact between the bearing and the stem of the electrode is poor, only a weak current can find its way to the point of contact, resulting in a feeble spark that may be too weak to fire the compressed mixture. Poor contact of the electrode may be caused by an inferior quality of lubricating oil forming a thin layer of carbon (which is a poor conductor) on the stem, or it may be due to wear of the bearing and a loose fit of the stem. To prevent wear on the stem and bearing it is important that the seat of the electrode be kept tight, so as to prevent the heat of the burning charge from reaching the stem and to keep it as cool as possible. This will aid in keeping the stem well lubricated, as the oil cannot be burned and form the objectionable carbon deposit. At the same time, the electrode will move easily without sticking, which is essential to a prompt separation of the two contact points.

76. Short Circuits.—A ground or short circuit of the current is often responsible for difficulties or failures of the igniter. This may be caused by carbonized oil on the exposed surface of the insulators, or by dampness between the mica washers if these are used for insulation. By placing the igniter plug in a warm place and drying it thoroughly, a short circuit of this kind can often be remedied.

77. Short-Time Contact.—The length of time during which the electrode points are in contact has a decided effect on the size of the spark. To test whether the contact is of sufficient duration, hold the two points together by exerting pressure by hand on the movable electrode. If this is found to cure the trouble, it is a sure indication that the contact is too short, and the parts that make the contact must then be adjusted so as to prolong the time of contact. This is accomplished in some igniters by increasing the tension of the igniter contact spring, while in others the adjustment is made by changing the relative positions of the interrupter lever of the movable electrode and the blade of the igniter lever that operates it and presses it against the fixed electrode.

78. Dirty Contact Points.—The contact points must be kept free from rust or moisture, both of which will interfere with the making of a bright spark. An occasional cleaning of the points by the use of emery cloth is advisable. Moisture on the electrode may be caused by condensation of the exhaust gases if the electrodes are very cold, which is likely to be the case in freezing weather before starting. The remedy is to heat the igniter plug thoroughly before attempting to start the engine. If moisture deposited on the electrodes is the result of a leaky packing or gasket, or of a defect in the cylinder, allowing water to enter the combustion chamber from the surrounding jacket space, it is possible to overcome this temporarily by wiping the interior of the combustion chamber dry with cotton waste or similar material. In this way the water may be kept away from the igniter long enough to get the engine started; but the real source of the trouble should be remedied at the earliest opportunity.

COIL DERANGEMENTS

79. Vibrator Out of Adjustment.—If the vibrator sticks, the symptoms will be erratic firing; few or no explosions will be missed, but the impulses will sometimes be very weak because the sticking causes a very late spark. Too light a pressure of the contact screw will cause the engine to run weak and fitfully; too much pressure will exhaust the battery rapidly. Either condition will manifest itself to the practiced ear by the sound of the vibrator. Poor firing may be caused also by pitting of the contact points. This may be remedied by filing the contact points, which should bear squarely against each other, and readjusting the spring and contact screw.

80. Defective Condenser.—A condenser short-circuited or having one of the connections broken will show it by sparking at the trembler and timer contacts, and by rapid burning of the metal where the spark occurs. The only remedy is to send the coil to the factory for repairs.

81. Short-Circuited Coil.—A spark coil may short circuit from breakdown of the insulation in either the primary or secondary winding. The symptom is a poor spark or none at all, and refusal of the vibrator to work, even with a good battery. The only remedy is to send the coil to the factory for repairs. The spark coil must be kept in a thoroughly dry place, as moisture will surely cause trouble and will interfere with the current passing through the coil to the engine. If the spark coil is found to be moist, it can generally be put in serviceable condition by drying it in an oven.

WIRING TROUBLES

82. Break in Primary Circuit.—The symptoms produced by a break in the primary circuit, which includes all wiring except from the coil to the plug, or from a secondary distributor to the plugs, are intermittent or complete failure to spark, according to whether the connection is intermittently restored by vibration or is wholly broken, and failure of the vibrators to work.

The almost invariable cause of breaks in the primary circuit is vibration, which will loosen nuts on binding posts and break wires in places sometimes quite unexpected.

The first step to be taken in remedying the trouble is to test every binding post, usually by shaking the wires with the fingers. If this does not disclose the trouble, hunt for a break in the wiring. It will generally be found close to a binding post, switch terminal, or other connection, where the bending due to vibration is most severe. As a last resort, close the switch, open the compression relief cocks, retard the spark, and turn the crank so as to make contact at the timer; then with a length of spare wire shunt successively each wire in the primary circuit by touching the ends of the spare wire to the ends of the regular wire until you have found the one with the break. The spare wire thus bridges the break in the regular wire and causes the igniter to operate. Then hunt down the break in that particular wire, or take it out and put in a new one. If the

wire has a soldered joint, it will be brittle at that joint and may have broken; or, it may have been fastened in such a manner as to strain it; or a badly made and twisted joint may have worked loose. Note that the break may be between the timer and the coil, in which case it will affect one coil only. A wire is quite likely to break inside its insulation, or just at the point where the insulation has been stripped off. A troublesome kind of break is that which is opened only by the vibration of running, and is closed by the elasticity of the wire or insulation, or by the weight of the battery cells or other connected members, when the car is stopped. A great deal of patience is sometimes needed to trace a break of this sort.

83. Short Circuit or Ground in Primary.—A short circuit or ground in the primary conductor is not a common trouble, and it can be avoided by the most ordinary care in insulating the primary. The symptoms are much like those due to a broken wire, but an ammeter test close to the battery will show that current is flowing. It is most likely to occur by the chafing through of the insulation of poorly supported wires, or by neglect to insulate properly some home-made attachment in the circuit. It may be due to contact of the dry primary cells or bolts passing through the battery box. A little patience is all that is needed to locate the trouble.

84. Broken Secondary Cable.—As the secondary cables are short and thick, a break in them is an unusual fault. If the break is not too great, the current will jump it, and the sparking there will at once disclose the trouble.

85. Grounded Secondary Cable.—A grounded secondary cable, which is indicated by failure to spark when the vibrator is working, is generally due to the chafing through of insulation on a badly supported cable. Sometimes it is due to rotting of rubber insulation by heat and oil. If the secondary cable has been spliced and taped, the current will go thr unless the cable is well out

of the way of grounded metal work near the splice. Such a cable may give a spark at the plug as well as at the ground, which will soon exhaust the battery.

The roadside remedy for a grounded secondary wire is to tie the cable clear of the metal work. The permanent remedy is to put in a fresh cable, adequately protected by fiber tubes or other insulating supports. A cable with a varnished exterior is the best, as it resists oil. A rubber-covered cable exposed to oil may be protected by a coat of shellac or a layer or two of tape.

86. Loose Electrical Connections.—To obviate failure to start because of loose or defective electrical connections, the ignition mechanism should be tested carefully. With the make-and-break system of ignition this is done by disconnecting the wire from the binding post or nut of the insulated electrode while the electrodes are in contact, and then snapping the end of the wire across the binding nut of the insulated electrode. If a good fat spark is produced when the wire slips off the nut, thus breaking the circuit, it is evident that the circuit is not defective beyond the igniter and that the contact between the electrodes is good.

If, with the wire connected to the insulated electrode and with the igniter contact points separated, a screwdriver were placed so as to make contact with the binding nut of the insulated electrode and with a capscrew, studbolt, or some bright part of the engine, the production of a spark when the contact between the screwdriver and the nut of the insulated electrode is broken would indicate that no short circuit exists in the igniter. If, however, no spark should be produced on breaking contact with the screwdriver, it would indicate the existence of a short circuit that should be found and eliminated. Should a spark be produced on breaking contact with the screwdriver when the two electrodes are in contact, it would be evidence of poor contact between the points. No spark will appear on breaking the circuit when the contact between the points is good.

The break of a wire inside the insulation, while not of

frequent occurrence, is harder to locate than a loose electrical connection. In cases where it appears impossible to find the trouble, the existence of the broken wire may be determined by running a temporary wire from the coil to the engine, spark coil, switch or battery, as the broken wire may be so situated as to show occasionally either an open or a closed circuit.

A loose rocker-arm fastened to the movable electrode will sometimes give considerable trouble that will be found difficult to locate. A very little lost motion where the shaft is small is increased rapidly; and, as soon as the shaft becomes the least bit loose, the pounding to which it is subjected will cause it to loosen very quickly.

Switches should have good, clean contact points, otherwise leaks will affect both systems of ignition.

TIMER TROUBLES

87. Timer Contacts Roughened by Sparking. Trouble due to roughening of the timer contacts by sparking is likely to occur in any timer in which the contact segments are inserted flush with the insulator barrel or internal ring, instead of projecting therefrom.

The symptom produced by roughened contacts is irregular firing, due to jumping of the contact roller or fingers. This is not noticeable at low speeds, but becomes marked as the speed increases. The remedy is to true the insulator ring and segments in a lathe, and, if necessary, put in a new roller or contact fingers.

88. Wabbling Timer.—Some timers have their stationary portion supported on the shaft by a very short bearing that quickly wears loose and allows the stationary portion to wabble out of its correct plane. This will cause irregular firing or even misfiring. One may easily determine whether the cause of the misfiring is here or elsewhere by steadying the timer with the hand. The remedy is to bush the bearing, and, if possible, to make it longer.

89. Incorrect Timing.—With marine engines having make-and-break ignition mechanism, even if the current is sufficient and there are no leaks, the time of contact may be too short, may be made at the wrong point in the stroke, or may be broken when it should not be, owing to incorrect timing. The timing may be tested by turning the flywheel carefully in the proper direction, and noting when the contact is made and at what point the spark occurs. By scratching the flywheel at these points, when the engine is running satisfactorily, it is always a simple matter to correct any trouble in the time of sparking. Raising or lowering the igniter pin without following any particular rule or without knowledge of what one is doing is very bad practice, and is more likely to aggravate than to remedy the difficulty. It is evident that, in multicylinder engines, it is quite important that there should be for each cylinder the same relative time of making and breaking the contact, with the same length of time in contact.

MISCELLANEOUS TROUBLES

CLOGGED MUFFLER

90. Habitual feeding of an excess of lubricating oil to the engine will gradually clog the muffler with a mixture of carbon and half-burned oil, which will reduce the power of the engine and be very difficult to remove.

The symptoms produced are loss of power and inability to speed up the engine when the mixture, compression, valve timing, and ignition are known to be good; if the exhaust pipes can be disconnected, the engine gives its full power at once.

To remedy the trouble, take off the muffler and saturate the interior with kerosene, after which the deposit can usually be knocked, scraped, or shaken out.

GASOLINE LEAKS

91. Probably the most dangerous trouble experienced with marine engines is due to leaks in the gasoline tanks or piping. They are more likely to occur at unions than anywhere else, and all joints and fittings should be soldered or brazed, as well as screwed. Hence, the piping is not liable to be broken at the threads, reinforced as they are with solder. Unions should be very heavy, and should be examined for leaks carefully and often. Do not use a light or match, but rub the finger around the joint, when, if there is a leak, it may be detected by the odor that will remain on the finger. Small leaks may be stopped temporarily by means of cloth and shellac or soap. Insulating tape will be found useless for the purpose, as the gasoline is a solvent for the insulating material.

A good cord closely and tightly wound will be found serviceable. Shellac and cloth bound on tightly and allowed to dry with no gasoline in the pipe will be found very effective in stopping leaks. It is necessary to be extremely careful of fire in the presence or suspected presence of gasoline, particularly when in the form of vapor and mixed with air.

WATER IN EXHAUST PIPE OR MUFFLER

92. The exhaust gases from stationary gas or gasoline engines contain a certain amount of moisture, part of which is condensed and deposited in the exhaust pipe or muffler, where it may become a source of trouble if no provision has been made to drain these connections properly or if the draining devices accidentally fail to perform their functions as expected. Especially during cold weather, when the condensation in the exhaust connections is greater than at more moderate temperatures, it is advisable to inspect closely the condition of the drain cocks. If neglected, the level of the water in the muffler may rise to such an extent as to prevent the exhaust gas from being expelled, first causing loss of power and finally stopping of the engine.

In engines in which the governor acts on the exhaust valve, and this valve is kept open while running under light load, the trouble from water in the exhaust, when no charges are admitted to the cylinder, is naturally intensified, on account of the fact that a portion of this water is drawn into the cylinder while the valve is open during the suction stroke. The presence of water in the exhaust connections is usually indicated by steam or water spray issuing from the end of the exhaust pipe.

As before stated, water is frequently used for deadening the noise of the exhaust by introducing it in a small steady stream into the exhaust pipe and allowing it to be carried off in the shape of vapor or spray with the exhaust gases. In such cases, the draining devices require particular attention, because, in the case of failure to have a free outlet to the drain for any part of the water not carried off with the exhaust, the accumulation of water would in a short time be sufficient to stop the engine.

WATER IN ENGINE CYLINDER

93. An accumulation of water in the cylinder—a condition encountered more or less frequently in marine practice—will effectually prevent a gas engine from starting. The water may get in through the exhaust pipe because the installation is faulty, because the exhaust extends below the surface of the water, or because there is a leak due to a crack in the cylinder or to a broken and imperfect gasket between the cylinder and the water-jacket. Running the exhaust cooling water into the engine exhaust is a frequent source of such trouble.

Provided the trouble from water in the cylinder is not due to leaks the remedy is to remove the water entirely, by means of absorbent materials, through any openings there may be in the cylinder. The insulated electrode should then be carefully dried out, the defect in installation remedied by changing the exhaust piping to drain outboard, and, if exhausting below the surface of the water, a vent provided in the highest part of the exhaust piping.

FAILURE TO GOVERN

94. If the connection between the governor and the throttle is too long, the throttle may fail to close until the governor balls have been moved out to an excessive extent by the speed of the engine. In an old engine, wear of the connecting links may produce the same result. Sometimes there is an adjustable screw and nut connection between the governor and the throttle, and this is easily adjusted. Sometimes, however, it may be necessary to bend the rod connecting the two. The throttle should be opened, and its position when barely open should be marked in such a way that it will be known when the throttle is reassembled. Then the engine should be run idle and the position of the governor lever noted when the engine is running at the speed at which it is desired that the governor should act. With these particulars known, it is easy to shorten the rod to bring the throttle to the desired position. It should be remembered that a very slight opening of the throttle is sufficient to keep the motor running

REPAIRS

CYLINDER AND PISTON REPAIR WORK

REFITTING PISTON AND PISTON RINGS

95. It is practically impossible to turn a piston in a lathe so as to fit the cylinder in such a manner that the engine will run properly even under a partial load. The best that can be done is to have the cylinder bored slightly larger at the end nearest the crank-shaft, so that the piston can be pushed in easily from this end and will fit rather snugly at the other end near the combustion chamber. To put the piston and cylinder in condition to stand constant running under load necessitates filing the surface of the piston by hand, as follows: See that both cylinder and piston are thoroughly clean and free from dust or filings. Apply a liberal amount of lubricating oil, place the piston in the cylinder, and attach the connecting-rod to the crank-shaft. Start the engine, and let it run idle for a while. As soon as the heat of the explosion causes the piston to expand, it will begin to stick in the cylinder, as the water-cooled walls of the cylinder do not expand to the same extent as the piston. The sticking is manifested by a pounding or knocking sound caused by the very slight amount of play that necessarily exists in the bearings of the connecting-rod at both the crankpin and the piston end. As soon as this pounding appears, apply more lubricating oil to the piston, and let it run for a few minutes in this manner, without any load. Then stop the engine, take out the piston, and wipe it dry. The portions of the piston that bear hard against the cylinder will be indicated by glossy spots, which should be carefully filed with a smooth, flat file, removing only a little at a time. To facilitate filing,

remove all traces of lubricating oil by means of kerosene. After filing the piston surface in this way, clean the piston, put it back in the engine, and start up again. It will be noticed that it is now possible to run the engine for a longer period without any pounding in the cylinder and perhaps to be able to put on a light load for a short time. Do not keep the engine running with any load for any length of time, so long as there is any pounding noticeable. This operation may have to be repeated from four to six times, depending on the skill of the operator, before the engine can run steadily with the usual maximum load.

These instructions apply also to cylinders that have been rebored and fitted with new pistons, as the conditions in this case are the same as in a new cylinder.

96. The piston rings also require fitting in a similar manner, and in this connection the following points must be observed: Before placing the rings in the grooves, each ring should be tried, to ascertain that it fits in the groove for which it is intended. If the ring is found too thick, place it on a straight board, and hold it in place by fastening three or four nails within the ring, driving them down until the heads are slightly below the top of the ring. Having thus secured the ring on the board, file it carefully and reduce its thickness so as to get an easy sliding and uniform fit in its groove.

The rings can now be put in place by opening them and slipping them over the piston from the closed end. In doing so, the rings should be expanded and twisted as little as possible. The first ring must be placed in the groove farthest away from the closed end of the piston, the others following in order. If, after running the engine with new rings for a short time, the rings show that they bear hard and unevenly, the hard-bearing portions must be touched up with a fine file. Should it become necessary at any time to replace a broken ring located between other rings, the use of small pieces of thin sheet tin will be found of advantage. They are slipped in between the inside of the ring and the outside of the piston, at a convenient point of the circumference, so as to

keep the ring evenly expanded and enable it to be moved laterally over other rings already in place to the groove for which it is intended. Having reached its groove, the pieces of tin are withdrawn, and the ring is allowed to enter the groove.

A ring that, from undue expansion or twisting, has lost its original diameter will not bear evenly and will wear out the cylinder in a short time, causing leakage and loss of power.

REPAIRING CRACKED WATER-JACKET

97. Neglect in draining the cylinder jacket when stopping the engine after the day's run may result in cracking the outer shell in cold weather, owing to the freezing of the water. It is very seldom that the inner cylinder is damaged in such a case, but if it should happen to be injured, the casting is generally rendered useless and must be replaced with a new one. The outer shell, being much lighter than the cylinder itself, provides a safeguard against damage to the latter, and in most cases, if the cylinder and jacket are cast in one piece, it will be possible and economical to repair the cracked shell.

The following directions are intended to cover repairs for various kinds of cracks, and apply to cracks in cylinder jackets proper, as well as to cracks in the outer shell of cylinder heads or valve casings of larger sizes. In large castings it will pay to repair the part, rather than replace it with a new one; but with small castings it may be found to be more convenient and cheaper to replace the heads or casings with new ones.

Fig. 4 (*a*) and (*b*) shows a cylinder, the outer shell of which has been burst by frost. The crack *a b* extends only a portion of the entire length. After the ice has been thawed and the jacket emptied, the first thing to do is to drill two holes *a* and *b*, about $\frac{1}{4}$ inch in diameter, at the ends of the crack. The purpose of these holes is to prevent the crack from extending any farther on account of the chipping necessary

n the next operation. Then take a chisel about $\frac{3}{16}$ inch to $\frac{1}{4}$ nch wide and cut a groove along the line of the crack, dove-ailed as shown at *c* in the sectional view of the cylinder and acket, Fig. 4 (*b*), the groove being widest at the bottom.

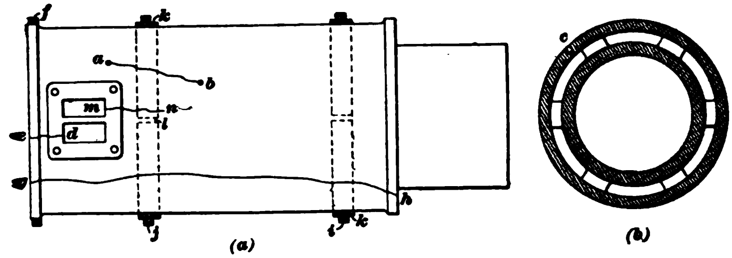


FIG. 4

Next secure a piece of $\frac{1}{4}$ inch round copper wire, well annealed, and hammer it tightly into the groove. By careful calking a crack of this nature can be made perfectly tight.

98. Fig. 4 (*a*) also shows a crack *dc* extending from one of the water ports to the outer end of the cylinder. In such a case, it will be necessary to shrink a steel band *f* on the end of the cylinder, before the crack is chipped out and calked in the manner just referred to. Use a flat steel band about $\frac{1}{2}$ inch by $\frac{3}{8}$ inch, and be sure that the finished end of the cylinder projects about $\frac{1}{8}$ inch beyond the band when in place.

If the crack extends over the entire length of the jacket, as shown at *gh*, it will require additional bands *i* and *j* as shown. If the cylinder has finished collars at the ends, as is frequently the case, it will not be possible to slip the ring *j* over the end of the cylinder into its proper place, unless an auxiliary band *k*, open to the extent of about $\frac{1}{4}$ inch as shown at *l*, is first placed on the cylinder. This band *k* must, of course, be thick enough to make up the difference in diameter of the cylinder body and the finished collar. In shrinking rings on a cylinder, they should be heated to a dull red heat and must be handled dexterously, as the cooling takes place rapidly and the ring may shrink so as to stick

before it reaches its position if not applied quickly. After the bands have been put in place and have been found to be tight, the cracks should be grooved and calked as directed.

If a crack should develop in the surface of a joint between the cylinder and one of the valve casings attached to it, and if this crack crosses the port through which the entering charge or the exhaust gases pass, as shown at *mn*, Fig. 4 (*a*), it will be practically impossible to repair the casting in such a manner that a packing can be made to stand, and the only remedy is to replace the damaged part with a new one.

99. Another method of repairing a short crack in the surface of the jacket wall consists in applying a piece of steel boiler plate, about $\frac{1}{8}$ inch thick. Before putting on the plate, two $\frac{1}{4}$ inch holes should be drilled at the ends of the crack, to prevent it from going farther, and a V-shaped groove cut along the crack from end to end. The plate must be bent so as to conform to the shape of the cylinder jacket. A packing of thin asbestos wick soaked in white-lead paste is now put in the V-shaped groove, after which a packing of sheet asbestos the size of the plate and dipped in water is placed over the surface to be covered by the plate. Now apply the plate, which is held in place by a number of $\frac{1}{4}$ inch to $\frac{3}{8}$ inch screws, the size of the screws depending on the thickness of the water-jacket. The screws should be about 1 inch apart, 1 inch on each side of the crack; and, if possible, the tapped holes in the jacket, in order to prevent water from leaking past the screws, should not be drilled all the way through. If the jacket is so thin as to make it necessary to drill the holes all the way through, each screw head must be packed with hemp or asbestos soaked in white lead.

100. An automobile-engine water-jacket split by freezing is also sometimes repaired by the following methods: If the crack is very small it may be rusted up. For this purpose, a saturated solution of salammoniac is made and poured into the jacket. A plug, screwed into one of the water openings, is drilled and tapped for a small tube, by

which air pressure is put on the liquid in the jacket by means of a tire pump. The cylinder is so laid that the crack is at the bottom, and after several hours it will be found that the edges of the crack have rusted solid from the action of the salammoniac.

Another method of closing a crack is that shown in Fig. 5. The process is to drill and tap a series of $\frac{1}{8}$ or $\frac{3}{16}$ inch holes as close together as practicable for the entire length of the crack, the first and last holes being at the extreme ends of the crack, in order to prevent it from extending farther. These holes are plugged with cast-iron plugs turned and threaded for the purpose, and the job is completed by rusting in with the salammoniac solution as just described. When brazing facilities are available, it is much better to braze a cracked cylinder than to try rusting it, as the chances of securing a permanent repair are much better.

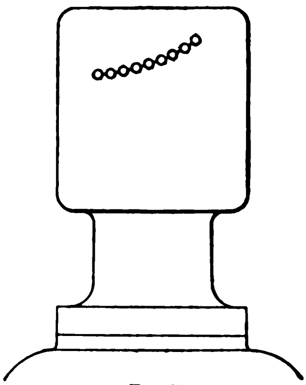


FIG. 5

MISCELLANEOUS REPAIRS AND RENEWALS

REPAIRING BROKEN ENGINE BED

101. The breaking of the studs or bolts that hold the connecting-rod box to the rod will often wreck an engine, involving the breaking beyond repair of the piston, cylinder, and even the bed. As the bed is usually a rather costly part to replace, it is frequently found possible to repair it with the aid of a strong steel rod properly applied.

A break repaired in this manner is shown in Fig. 6. It is possible to make this kind of repair only when there is a clean separation of the casting in two pieces; if the bed is broken into a number of small pieces, it must be replaced with a new casting.

To repair a bed, as shown in Fig. 6, first be careful to preserve the two pieces so that they will fit exactly when put together, using every precaution against careless handling and further damage to the surfaces that form the joint. Then investigate and find the best way in which the steel

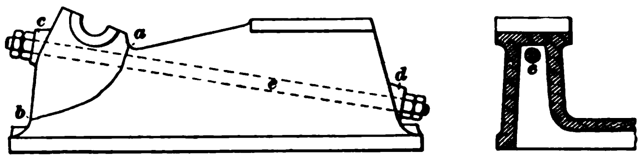


FIG. 6

rod should be run so as to take hold of the strongest available part of the bed.

The figure shows the rod running inside of the double wall casting, a 2-inch rod being used in a space 3 inches wide, and being secured by two nuts at each end. The line *ab* indicates the break of the bed casting. At *c* and *d* are cast-iron washers made to conform to the shape of the casting and providing a straight surface for the nuts of the bolts *e* to rest on. It is important that the nuts should bear squarely against these washers to avoid any excessive stress on the bed casting. Jamb nuts or some other locking device must be provided to prevent the nuts that hold the bed together from becoming loose as a result of the shocks and jars to which the casting is subjected while the engine is running. A frequent inspection of the tightness of the nuts is advisable.

REGRINDING VALVES

102. It is not often that inlet valves must be reground, because they remain comparatively cool under the influence of the incoming charge, and, moreover, the seats are not exposed to the erosion of burning gases. Exhaust valves, on the other hand, require regrinding at intervals, depending somewhat on the temperatures in the cylinder, and to a large extent on the material of which the exhaust

valves are made. Ordinary mild-steel valves must be reground quite frequently. A much better material is an alloy of nickel and steel containing a high percentage of the former metal, usually about 25 per cent. Such an alloy as this has a very small coefficient of expansion, and is less subject to erosion due to the heated gases. Moreover, it is not liable to warp out of shape.

For large engines, and occasionally for small ones also, cast iron has been found to be a very good material for the exhaust valves. If cast iron is used, the stems and heads are made separate; the stems are made of steel, and the heads are riveted on the stems. The only drawback to cast iron for this purpose is that it has not the strength of steel, and the valve head must be of unusual thickness, which, of course, adds to the weight and inertia of the valve.

103. Inlet and exhaust valves are reground with emery. If an exhaust valve, the spring is first slipped off to make sure that there is no sidewise pressure on the stem to prevent a true bearing of the valve on its seat. The emery is mixed with oil until it forms a paste, and is applied freely to the surface of the valve and its seat. Extreme care must be taken to prevent any of the emery from getting into the interior of the cylinder, where it would quickly ruin the piston and the cylinder walls. In some cases, a plug of waste can be thrust into the valve chamber between the valve and the piston; but, if the chamber is not long enough for this, the work will have to be watched carefully, using an electric light, if necessary, to see that none of the paste works away from the valve toward the piston.

104. If the valve seat is badly out of true, the operation of grinding may be begun with emery of medium coarseness; but this is seldom necessary, for the reason that, before the valve had reached such a condition, the cylinder in question would have lost almost all of its power. In any case, the work is finished with fine flour of emery. The emery being applied, the valve is set into its place in the valve seat, and a screwdriver is used in the slot in the valve

head to rotate the valve, which should be worked by quarter-turns back and forth with moderate pressure, and should be lifted at frequent intervals to allow the paste to work in between the valve and its seat. In order to grind the valve evenly all around, it should occasionally be advanced a quarter-turn, and the grinding-in process continued. When the grinding is almost finished, the pressure should be comparatively light.

If the valve has been pitted, it will not be necessary to grind it until the pits have entirely disappeared, so long as there is a good bearing around them.

When the work is finished, the ground portion of the valve should have a smooth, dull appearance, and neither the valve nor its seat should at any point be bright, as this would indicate that metal had been rubbing on metal without emery between.

105. After the valve has been reground several times, it is likely to have settled so much lower in its seat as to cause the valve stem to remain in contact with the push rod when the valve is supposed to be seated. When the valve is closed, the clearance between the valve and the push rod should be fully equal to the thickness of an ordinary visiting card. If the distance is less than this, any slight irregularity in the cam, or some slight springing of the metal parts when the engine is running, might bring the valve stem and the push rod together and cause the valve to be opened slightly.

106. In an old motor it may be found that the bushing or sleeve in which the valve stem runs is worn to such an extent as to permit considerable sidewise movement of the stem. A valve in this condition will still operate if it has been carefully ground, but it is likely to need grinding much oftener than if it were truly guided by its bearing. It should never be ground with the spring washer merely blocked up; the spring should in each case be wholly removed.

RENEWING BABBITT-METAL LINERS

107. When a babbitt-lined bearing becomes overheated and the trouble is not noticed in time, the soft metal of the lining, which may have a tin or a lead base, will melt and run out of the box. While in some engines the Babbitt metal is cast directly in the rough bearings of the engine bed, it is the general practice in a first-class engine to bore out the bearings in the bed and fit them with cast-iron or bronze boxes lined with Babbitt metal.

If the journals of the shaft are in good condition after the metal has been melted and run out of the box, the method of rebabbitting the bearing is the same as was followed at

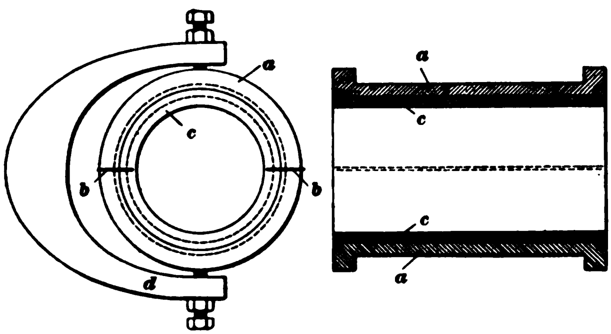


FIG. 7

the time the box was made at the factory. To reline the box in such a case, proceed as follows: Remove all traces of the original lining from the box. While melting the new metal in the ladle, place the box on its end on a flat-finished surface, and insert an arbor, from $\frac{1}{8}$ to $\frac{1}{4}$ inch smaller in diameter than the journal, in the center of the box, being careful to have an evenly divided space all around the outside of the arbor. The box *a* being made in halves, as shown in Fig. 7, place shims *b*, *b* made of cardboard $\frac{1}{32}$ inch thick between the joints, having the shims extend well into the space around the arbor so as to allow only a thin strip of the Babbitt liner *c* to connect the halves of the lining, in

der head to the cylinder, screw the nuts on the studs, and tighten them gradually and evenly. After everything has been put in order, start the engine and run it under a light load or idle, until it begins to warm up, when it is found that the nuts can be tightened up still more. This should be done promptly, as neglect to take up any expansion by the heat of the combustion may cause the new packing to become leaky soon after it has been put in.

111. While the packing surfaces must be true and straight, it does not follow that they should be as smooth as glass. Experience has shown that a grooved packing surface gives much better results than a perfectly smooth one, although many manufacturers seem to take great pains to make the packing surfaces as smooth as possible. In many cases, troublesome joints have been permanently cured by the judicious application of grooves in the metal surfaces. The packing fills the grooves and prevents the escape of gas between the packed surfaces. Fig. 8 shows, in dotted lines, the positions of the grooves *c*, which in small surfaces may be $\frac{1}{32}$ inch deep and $\frac{1}{16}$ inch wide. On circular surfaces, such as the packing surface between the cylinder and the cylinder head, shown in Fig. 9, the grooves should be cut concentric, and should not come opposite each other; but, when placed together, the groove *a* in the cylinder *b* should be half way between the grooves in the head *c*, as shown.

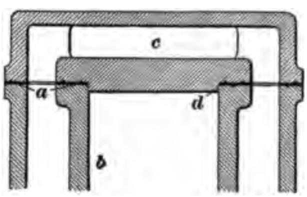


FIG. 9

112. Whenever possible, the edge of the packing should be protected against the pressure by a projecting rim *d*, that enters the end of the cylinder, as shown in Fig. 9. If not originally provided by the maker of the engine, it will pay the user to have the rim attached by riveting it to the cylinder head, in case of persistent trouble with the packing of this joint. The depth of the projection *d* should be about $\frac{1}{4}$ inch, and it should fit rather snugly in the bore of the cylinder,

but not so that much force will be required to insert the head.

113. As the material employed for gaskets is usually asbestos alone, or asbestos, wire gauze, and graphite or similar filler, a knife or pair of scissors makes very little impression on it; but it can be cut out very readily if laid on the cylinder head and carefully cut around on the outside with a light, flat-faced, round-peen hammer. The holes can then also be cut with the round peen. Great care should be exercised not to pull out any wires from gaskets in which wire gauze is used. The wires should be cut off very carefully.

If the material used is ordinary asbestos paper $\frac{1}{100}$, $\frac{1}{64}$, $\frac{1}{32}$, or even $\frac{1}{16}$ inch thick, it should be thoroughly soaked with linseed oil, either raw or boiled, and dusted carefully with powdered or flaked graphite, or with graphite foundry facing that contains talc, etc., which is a very good substitute. It is a good plan to let this dry a little while in the air, when it becomes much tougher. It should not, however, be allowed to get too dry. When put in place, the holding nuts should be screwed down carefully, going over them several times and screwing down opposite nuts instead of adjoining ones. The engine should then be started and run a few minutes, with the compression relieved and the circulating water turned off, in order to heat up the engine and assist in drying out the oil or any dampness in the gasket. The nuts should then be tightened carefully, when the water may safely be turned on. If these directions are followed closely, and the gasket is not defective, it should last a long time. The oxidation of the linseed oil will make the gasket tough, and if it is dusted with graphite every time the cylinder head is removed it should be very durable.

In using a gasket of asbestos and wire gauze having material on one side to make it adhere to the cylinder top, the opposite side being treated with graphite, there is no need of treating the gasket with linseed oil. A gasket of this sort is almost indestructible when care is exercised in tightening the holding nuts when the gasket is new.

POWER DETERMINATIONS

TESTING

EQUIPMENT FOR TESTS

OBJECT OF TEST

1. There are occasions when it is necessary or advisable to make a careful study of the performance of a gas engine under various conditions of working. For example, a manufacturer may be looking for defects, in order to apply the proper remedies; or, he may desire to possess a record, in order to offset possible complaints from purchasers regarding the non-fulfilment of the requirements of contracts. Also, a prospective buyer may want a test made for purposes of comparison with other engines, or of determining the make best suited to his needs; or, a user may have trouble with his gas engine and make a test to locate the difficulty, and, after repairs are made, make another test to ascertain whether the engine is in order. In cases like these, a properly conducted test will bring out the good and the bad features of an engine as nothing else will. A thorough test will enable the engineer to determine whether the engine is wasting power, and, if so, to discover the cause; to ascertain whether the engine is correctly designed with regard to the sizes and proportions of valves and passages, and whether the valves are properly set; and to locate many other faults that would probably be overlooked and that continuous running would perhaps never reveal.

While, however, a complete test is very often desirable, it is not always necessary. Perhaps all that may be desired will be the power that the engine can deliver to the machinery it is intended to drive, in which case a brake test only will be required. In order, however, that every detail may be understood, a test in its entirety will be described, so that whatever portions are required in actual practice may be used when wanted.

2. In a gas-engine test, the following results are usually determined in order that the performance of the engine may be ascertained: (1) the brake horsepower; (2) the indicated horsepower; (3) the quantity of gas consumed per brake horsepower per hour; and (4) the lost energy due to heat carried away through the exhaust, by the jacket water, and by radiation from various parts of the engine.

The **indicated horsepower** (sometimes abbreviated to I. H. P.), so called because it is measured by means of an indicator, is the power applied to the piston of the engine by the explosion and expansion of the gases.

The **delivered horsepower** (abbreviated to D. H. P.) is the name given to the power delivered by the engine to the belt or the machinery it is driving. The delivered horsepower is frequently called the **brake horsepower** (abbreviated to B. H. P.), because it is measured by means of a brake.

From the measurements that must be taken to obtain the data just given, the performance of any engine can be readily analyzed.

APPARATUS USED IN TESTING

3. Prony Brake.—To make a test as just indicated, it is necessary to have an apparatus similar to that shown in Fig. 1, which is a view of a form of absorption dynamometer known as the **Prony brake** and used to obtain the brake horsepower. The Prony brake consists of an iron strap *a*, to which are attached, with screws, a number of wooden friction blocks *b*. To each end of the strap is bolted a cast-iron

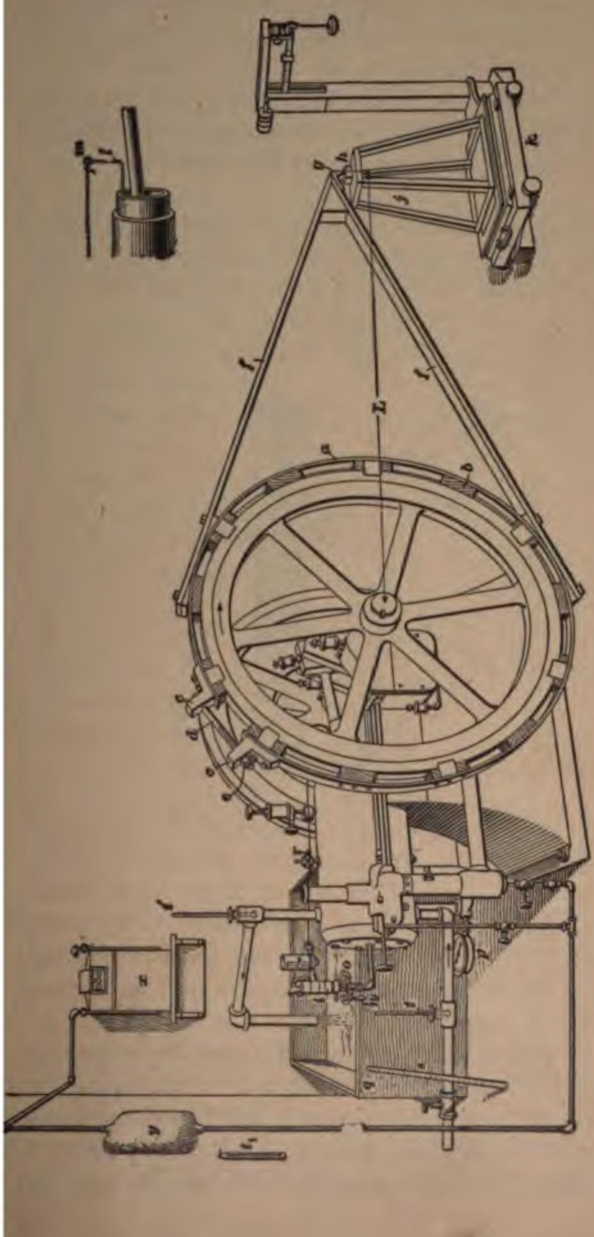


Fig. 1

block *c*, so that the brake may be tightened by means of th bolt *d* and the nut *e*. Bolted to *a* are two boards *f*, *f*, formin the lever arm, or brake arm, and carrying at one end th steel knife edge *g*. This knife edge rests on a flat piece iron *h*, through which the pressure is transmitted to th platform scale *k* by means of the stand *j*.

4. **Rope Brake.**—A simpler form of brake, and or suitable for light powers, is shown in Fig. 2. The brake proper consists of four or five ropes, as shown at *r*, or a piece of leather or canvas belting. The weight *w* is fastened to one end of the belt and a spring balance *b* to the other. The lower end of the balance is attached to a hook *h* screwed fast to the floor. If the pulley were perfectly free to turn, the reading on the balance would be equal to the weight of *w*; that is, if the weight of *w* is 50 pounds, the pointer on the balance will be at 50.

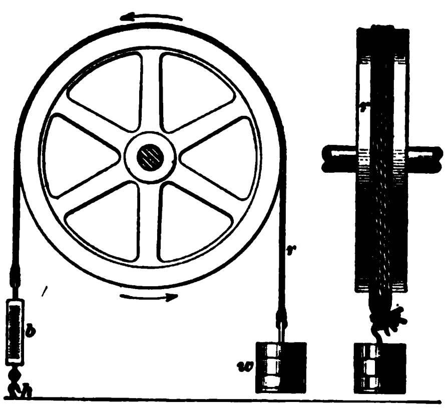


FIG. 2

As the pulley is turned by the engine, the weight *w* is drawn upwards by the friction of the strap until the strap slips on the pulley. The total amount of pull will then be indicated by the decrease in the reading of the balance, or by the difference between the weight of *w* and the balance reading. Thus, if the balance reads 20 pounds, the pull on the belt will be $w - 20$, or $50 - 20 = 30$ pounds.

It is evident that, in either form of brake, the energy absorbed is converted into heat by overcoming the force of friction between the brake and the revolving wheel. In the simple forms of brake mentioned, it is a serious problem to take care of the heat generated at high speeds, and for this

on such brakes cannot be used on gas engines except short periods of time, unless the heat is absorbed by ɛr.

, **The Alden Dynamometer.**—The **Alden dynaneter** is a type of brake that can be run continuously very little attention. Fig. 3 shows an elevation and part ion of such a dynamometer. It consists of the hub and casting *a*, the shaft *b* to which the casting is keyed, the ɩing plates *c*, *c*, and the thin copper plates *d*, *d*. The copplates are clamped at the outer edges between the two ɩing plates, and at the inner edges between rings and hubs of the housing plates. The copper plates are thus parallel and close to the disk *a*, in which are radial oil ›ves for conducting oil all over the bearing surface reen the disk and the copper plates. Oil is fed to these ›ves from the oil cups *e*, *e*, through the pipes *f*, *f* and the ›assages *g*, *g*, in the housing hubs. The oil that works ray out around the hub to the recesses *h*, *h* is drained off ugh the pipes *i*, *i*. The copper plates and the housing ɛs form chambers *j*, *j*, which are filled with running water n the apparatus is in use. Water enters the bottom of e chambers through the pipe *k*, the automatic regulating e *l*, and the pipe *m*. From the pipe *m*, the water passes ugh openings in the bottom casting *n* into the chamj, *j* in the housing. The water fills the chambers, rises the space *o*, and flows out through the pipe *p*. The ɪr pressure in the chambers *j*, *j* forces the copper plates nst the disk *a*, and sets up a friction that heats the copplates and tends to turn them with the disk. The heat rried off by the water, while the tendency of the copper ɛs and housing to turn is balanced and weighed by the ;ht *q* on the arm *r*. If the water pressure increases, the *r* goes up and partly closes the automatic valve *l*, thus ›ring the equilibrium.

rnamometers of the Alden type have been built with ɛ or four disks and large enough to absorb 2,000 to) horsepower at from 200 to 300 revolutions per minute.

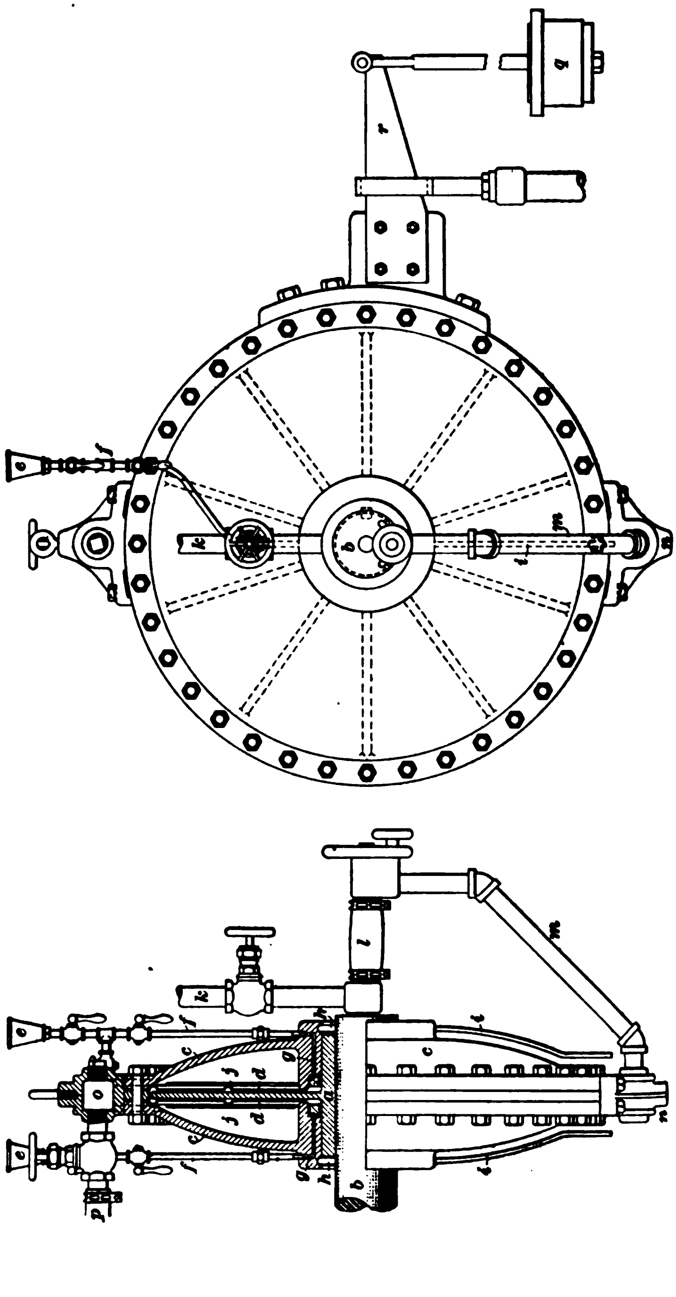


Fig. 3

6. The Dynamo as a Dynamometer.—One of the best means of absorbing work from a gas engine and converting it into heat is to use a dynamo, which for dynamometer purposes is preferably coupled to the shaft of the gas engine—that is, the dynamo and engine are direct-connected. The electricity delivered by the dynamo is absorbed by passing it through a suitable resistance. The product of the readings of the ammeter and voltmeter placed in circuit gives the number of watts generated, which, divided by 746, will give the horsepower generated by the dynamo. To obtain the delivered, or brake, horsepower of the gas engine, divide this result by the efficiency of the dynamo, which has been previously determined at the load required.

7. The Gas-Engine Indicator.—In making a test of a gas engine, the power exerted on the piston by the explosion and expansion of the charge is measured by means of an instrument known as an **indicator**, and shown at *i*, Fig. 1. The indicator used on gas engines is very similar to that used on ordinary steam engines; in fact, the same indicator is often used for both, with auxiliary attachments to adapt it to the gas engine. The piston of a gas-engine indicator should, however, be very light in order to give the best results.

The purpose of the indicator is to determine the pressures in the engine cylinder at all points of the stroke, and to record these pressures in the form of a diagram on a paper or a card. In the case of the gas engine, the principal reason for obtaining an indicator diagram is to determine the correct setting of the valves and the timing of ignition. The mean pressure may also be found, approximately, by the indicator diagram; but the shock of the explosion, the high speed of the engine, and the inertia of the indicator-pencil motion tend to reduce its accuracy for that purpose.

8. Fig. 4 shows the general appearance of an indicator. The instrument consists essentially of a cylinder *a* containing a piston and helical spring for measuring the pressure, the lever *b* for transmitting the motion of the piston to a

pencil point *c*, and the drum *d* that carries the paper, or card, on which the diagram of the motion is drawn. The card *e* is held close to the drum by the clips shown at *f*, *f*, so that the pencil can easily trace the outline of the diagram.

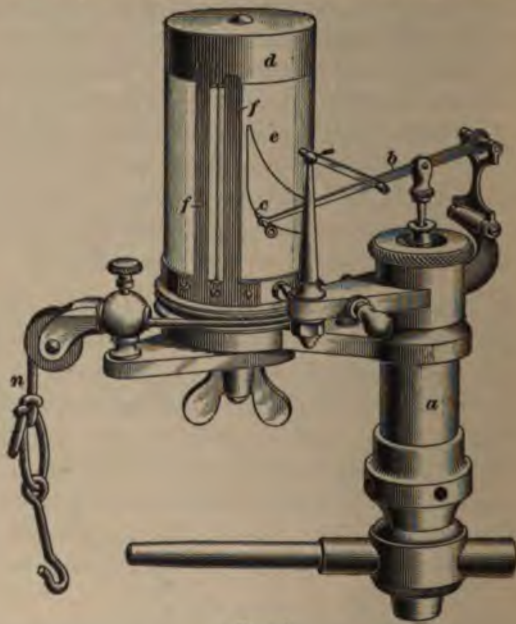


FIG. 4

In Fig. 5 is shown a section of the same indicator. The piston, shown at *g*, must work in the cylinder as nearly frictionless as possible, the spring *h* being the only resistance to its upward motion. The spring is calibrated, that is, tested so as to determine the pressures required to move the pencil *c* to various heights against the resistance of the spring. The pressure, in pounds per square inch, that is required to compress the spring sufficiently to allow the pencil to be moved up 1 inch is called the **scale of the spring.** It is, therefore, possible to find the pressure in the cylinder by the position of the pencil point when the scale of the spring is known. By turning a small cock, shown at *o*, Fig. 1, in the pipe connecting the indicator to the engine

cylinder, the gas pressure in the engine cylinder may, at pleasure, be admitted to or shut off from the indicator. When the gas pressure is admitted through the channel *s*, Fig. 5, it causes the piston *g* to rise. The helical spring *h*

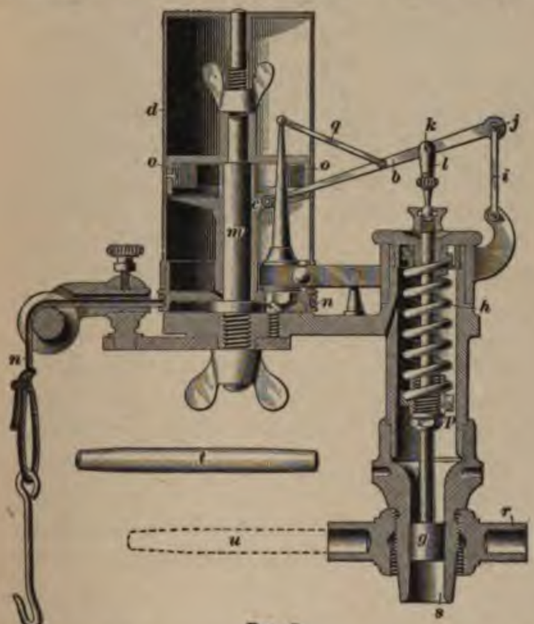


FIG. 5

is compressed and resists the upward movement of the piston. The height to which the piston rises should then indicate correctly the pressure in the engine cylinder; and as this pressure rises and falls, the piston *g* must rise and fall accordingly.

9. To register the engine-cylinder pressure, a pencil might simply be attached to the end of the piston rod, and the point of the pencil made to press against a piece of paper. It is desirable, however, to restrict the maximum travel of the piston to about $\frac{1}{2}$ inch, while the height of the diagram may advantageously be $1\frac{1}{2}$ to $1\frac{3}{4}$ inches. To give a long range to the pencil while keeping the travel of the piston short, the pencil is attached at *c*, Fig. 5, to the long

end of the lever *b*. The fulcrum of the lever is at *j*, and the piston rod is connected to it at *k*, through the link *l*. The pencil motion is thus much greater than the travel of the piston *g*; for most indicators, it is four, five, or six times as great. The point *c* is made to move in a vertical straight line by the arrangement of the links *i*, *l*, and *q*.

10. The indicator, however, must not only register pressure, but must also register them in relation to the position of the piston. This registering is accomplished by means of the cylindrical drum shown at *d*, Figs. 4 and 5. The drum can be revolved on its axis *m* by pulling the cord *n* that is coiled around it. When the pull is released, the spring *o*, Fig. 5, turns the drum back to its original position. If the cord *n* is attached to some part of the engine that has a motion proportional to the motion of the piston, the motion of the drum must also be proportional to the motion of the piston. If the cord were attached directly to the piston or to some part having the same motion as the piston, the drum *d* would have to be so large that it would be cumbersome and the diagram correspondingly long and difficult to handle. For these reasons, the drum is made small and a device is employed for reducing the motion of the drum so as to give a convenient length of the diagram. This device, called a *reducing motion*, will be explained later.

The indicator shown in Figs. 4 and 5 can be used in taking diagrams from a steam engine or any other engine in which the pressure is not so great as in the gas engine. In order to do this, the piston *g* and its rod are unscrewed at *p* and a piston that just fits the cylinder at *p* is attached. The area of the cylinder at this point is just twice that of the piston *g*; hence, only one-half as much pressure per square inch will be required to produce the same pencil movement.

11. To attach the indicator to the engine, a hole is drilled in the cylinder head into the clearance space of the engine and tapped for a ½-inch pipe, shown at *n*, Fig. 1, with an elbow turned up and carrying a nipple and a valve *o* next to the indicator. The lower end *s*, Fig. 5, is inserted in the

fitting attached to the valve and the connection *r* is tightened by means of the handle *t* shown dotted at *u*. When the indicator is to be used, a card or a piece of blank paper of convenient size is placed around the drum, with the ends of the paper projecting from behind the clips through the space between them. The drum revolves with a motion proportional to the stroke of the engine, and the pencil moves up and down with a motion proportional to the pressure in the cylinder. Hence, by holding the pencil against the paper it draws a diagram recording these two quantities in such a way that they can be measured for every point of the stroke.

12. Manufacturers of indicators usually supply a special paper for use on the indicator, known as "metallic paper," which is made by coating ordinary paper with a special preparation that will turn black when rubbed with a brass wire. The indicator pencil may then be replaced by a piece of ordinary brass spring wire, and the trouble of keeping a pencil sharp is obviated. Although the preparation of this paper is usually considered a secret, a coating of zinc oxide (zinc white, or Chinese white) will answer the same purpose. The zinc oxide is mixed with some gum solution or glue, and spread evenly over the surface of the paper. The paper is then allowed to dry, and is afterwards subjected to pressure for a day or two to remove the tendency to curl. The surface should be smooth and free from lumps or ridges, as these will cause unnecessary friction. Diagrams made on metallic paper are much more distinct than those made in the old way with a hard pencil.

13. The indicator spring to be chosen depends entirely on the initial pressure of the exploded charge. The scale of the spring should be such as to give not over $1\frac{3}{4}$ inches vertical movement to the pencil for the highest pressure to be obtained on the cylinder. For instance, if the initial pressure is 175 pounds, a 100-pound or 120-pound spring should be chosen. The scale of the spring (100 pounds) indicates that the pencil will move 1 inch for each 100 pounds pressure per square inch on the piston. In general, it is

advisable to select a spring that will give a diagram between $1\frac{1}{2}$ and $1\frac{3}{4}$ inches high. A diagram less than $1\frac{1}{2}$ inches in height is objectionable, for it is too small to show properly the valve setting; hence, in such cases, it is advisable to use a spring of lower scale. It may be found necessary to provide the indicator with a safety stop, so that the piston will not rise too high and thus cause damage to the spring and other moving parts.

The cylinder of the indicator *i*, Fig. 1, is connected to the compression space by $\frac{1}{2}$-inch gas pipe, as shown, a plug cock *o* being inserted between the engine and the indicator. A bunch of waste saturated with water should be tied around the indicator at *o* and kept wet constantly, in order to prevent damage to the indicator from overheating.

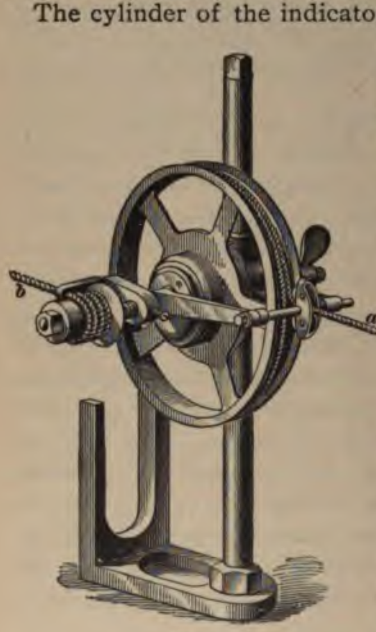


FIG. 6

14. Reducing Motions. There are many devices—known as **reducing motions**—for reducing the motion of the engine piston to one suitable for the indicator drum. The reducing wheel *r*, Fig. 1, is perhaps the most convenient for general use. It is shown on a larger scale in Fig. 6; the cord *a* is attached to a rod on the piston, and the cord *b* is attached to the indicator drum.

The other end of the cord *a* is attached to the large wheel and wound several times around it. As the cord *a* is pulled by the piston, it unwinds, turning the large wheel and the small wheel at the same time. The spindle of the small wheel has a screw thread of a pitch equal to the thickness of the cord, so that the arms of the cord guides, which are

held from turning about the spindle, are moved, with each revolution, along the spindle a distance equal to the thickness of the cord. Hence, the cords never wind over themselves, but each cord is laid up in a continuous coil on the pulley as the other unwinds from its pulley. The pulleys being fastened together, the smaller turns with the larger; and, as the cord *a* unwinds one turn from the large pulley, the cord *b* unwinds from the indicator drum and winds one turn on the smaller pulley. Hence, the motion of the two cords is proportional to the circumferences or diameters of the two pulleys.

The smaller pulley can be removed and replaced by one of several others of different sizes. The proportions of the two pulleys should be such that the length of the diagram will be between $2\frac{1}{2}$ and $3\frac{1}{2}$ inches. Thus, if the stroke of the engine is 12 inches, and the desired length of the diagram is 3 inches, the diameter of the larger pulley should be four times that of the smaller.

15. The small sketch at the right of Fig. 1 illustrates the method of connecting the cord from the reducing wheel to the engine piston. A $\frac{1}{4}$-inch iron rod *l* is bent at right angles, as shown, and attached to the inside of the piston by two or three small machine screws. The end attached to the piston should, of course, be drawn out flat before the holes for the screws are drilled. A hook is made at *m*, to which the cord from the reducing wheel is to be attached. The wheel can be placed at any convenient point between the point *m* and the indicator.

16. Reducing motions that employ gears are frequently used. Such a reducing motion, attached to an indicator, is shown in Fig. 7. This motion really consists of two wheels; on the larger one, shown at *a*, is wound the cord that is attached to the rod on the piston, and from the smaller one *b* runs the cord to the indicator drum. A spring in the horizontal case *c* acts on the pulley *a* through the bevel gears, resisting the pull of the piston on the string, on its outward stroke, and drawing in the string on the return

stroke, thus always keeping the string tight. In the same way, the spring in the indicator drum *d* keeps the string tight between the drum and the pulley *b*. Frequently, the reducing wheel is attached directly to the body of the indicator, as shown in Fig. 7, thus avoiding the necessity of fastening it to the engine, as shown in Fig. 1. When the reducing wheel is attached directly to the indicator, the cord from the wheel *b*, Fig. 7, to the indicator drum *d* is short and direct, making a connection with very little lost motion. The wheel *a* is very easily detached from the mechanism, and is one of several different sizes furnished with the apparatus, and used on engines of different lengths of stroke. The cord guide *e* is arranged so that it can be turned to any position in its horizontal plane and fastened there, when it has only the vertical motion necessary to lay the cord on the wheel uniformly.

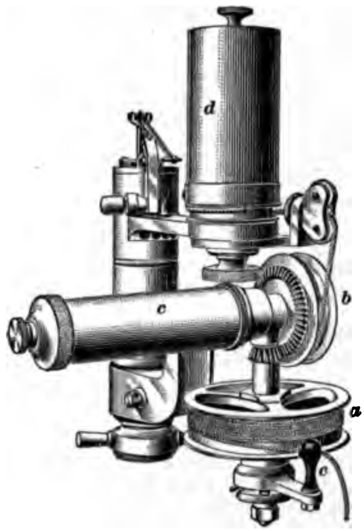


FIG. 7

17. There should be some means arranged to stop the motion of the drum when not in use. This is easily done by dividing the cord from the indicator drum to the reducing wheel, and connecting the two portions by means of the loop *l* and hook *a*, Fig. 8. The knots should be so tied that they will not slip. The small piece of wood *b* makes a very neat arrangement about which to make the loop, as it will not slip and is easily united, and the length of cord is readily adjusted. In case the reducing wheel is connected to the

FIG. 8

indicator, as shown in Fig. 7, the hook is placed in the cord running from the reducing wheel to the rod on the piston.

18. Gas Measurement.—The gas that is supplied to the engine should be measured by a proving meter connected as shown at x, Fig. 1. Such a meter has a large dial and gives the number of cubic feet per hour from an observation of 1 minute, as well as the total gas consumption over any period of time. The gas from the meter should pass to the engine through an india-rubber gas bag y, or some other form of pressure equalizer. In gasoline- or oil-engine tests, the fuel must be weighed.

19. When it is necessary to measure the heat wastes and calculate the ratio each bears to the heat supplied, the heating value of the gas should be obtained. Quite frequently, the gas company has a record of the average heating value of the gas it manufactures. If it has no such record, a sample of the gas should be sent to a laboratory to be properly tested for this value. This determination is absolutely essential to a complete test, or for a comparison of engines tested with different grades of gas.

20. Cooling-Water Tanks.—In order to ascertain the amount of heat carried off by the jacket water, it is necessary to know the weight of water that passes through the jacket and the rise of temperature caused by the heat of the engine. The weight of water may be measured in one of two ways: the water may be weighed directly, by means of a platform scale, using a tank or barrel set on the scale platform; or, if the scale is not convenient, the volume may be measured and the weight calculated. Since a certain volume of pure water at the same temperature always has the same weight, it is a simple matter to measure the water directly in pounds. For this purpose, the measuring tank q, Fig. 1, is so constructed that the depth of the water, in inches, gives its weight, in hundreds of pounds, when multiplied by 2. The tank is made of plank, and measures $37\frac{1}{2}$ in. $\times$ $37\frac{1}{2}$ in. inside dimensions. The height may be from 2 to 3 feet, as found most convenient. The stick s is marked off in inches or

$\frac{1}{2}$ inches as desired. This is used for measuring the depth of water in the tank. When the bottom of the tank is level, each 2 inches in depth indicates 100 pounds of water, and each $\frac{1}{2}$ inch 25 pounds of water. If the stick is marked off in tenths of an inch, each tenth will indicate 5 pounds of water. These dimensions are computed for water at a temperature of 110° F. If a smaller tank or more accurate measurement is required, a tank $26\frac{1}{2}$ in. $\times$ $26\frac{1}{2}$ in. will give 25 pounds for each inch on the stick, 100 pounds for each 4 inches, and 5 pounds for each $\frac{1}{5}$ inch.

When the quantity of water used is small, or when very accurate determinations are to be made, the water should be weighed. This can be done quite readily by using two receptacles and changing them at the moment of taking the reading. For instance, if the reading is taken every 5 minutes, the stream should be changed from one to the other, just as the signal is given.

Fig. 9

The temperature of the entering water is taken by a thermometer at t, and that of the discharge at t'. The thermometers are not directly in contact with the water, but are inserted in small cups containing oil. The temperature of the room is taken by the thermometer t_1.

21. Pyrometer.—The temperature of the exhaust gases must be taken in order to determine the loss of heat by way of the exhaust pipe. As these temperatures are too high for the mercury thermometer, a form of temperature indicator known as a **pyrometer** is generally used instead. A pyrometer is shown in Fig. 9. The stem s is composed of two tubes made from metals having different rates of expansion. The metals generally used are copper and iron, the copper tube being

aced inside the iron tube, or vice versa. The entire stem om the nut k should be subject to the temperature it is sired to measure. nce the outside tube is ated first, the pointer quently moves rapy forwards or backrds around the dial. soon as the stem is oroughly heated, the inter will indicate the temperature of the gases. A pyrometer is also shown at p, Fig. 1.

FIG. 10

22. Revolution Counter.—The engineer should be provided with one of the three forms of revolution counters shown in Figs. 10, 11, and 12. The first is a *continuous counter*, the second a *speed indicator*, and the third a *tachometer*.

The arm a of the **revolution counter**, shown in Fig. 10, is attached to some reciprocating part of the engine. The number of revolutions per minute may be determined by means of a watch, and the number registered at the beginning and end of a minute noted. The difference between the second and the first reading will be the number of revolutions per minute. The readings of the counter may, instead, be noted at regular intervals (say of 10 minutes each), and the total number of revolutions registered during that time divided by the number of minutes; the result will be the number of revolutions per minute.

FIG. 11

23. Speed Indicator.—The **speed** **dicator,** shown in Fig. 11, registers the total number of

FIG. 12

revolutions. It is used as follows: The handle h is held in the hand, and the soft rubber point p is thrust into the center countersink on the end of the crank-shaft; the dial d will then register the number of revolutions. The best way to use this instrument is to have an assistant observe the time. He should give the signal "go" at the beginning of the minute, and the signal "stop" just as the minute is up. First, set the instrument at zero, or carefully note the reading of the dial. Then, hold the point p opposite the center, and at the signal "go" thrust p into the center, holding it tight enough to prevent it from slipping. Note the number of revolutions of the dial, and at the signal "stop" immediately draw the indicator away from the shaft. As the dial reads to 100, each revolution of the dial will mean 100 revolutions of the crank-shaft. Thus, if the dial makes two turns and the pointer stops at 50, the number of revolutions is 250.

24. The Tachometer. The **tachometer,** which is

shown in Fig. 12, is an instrument for measuring the number of revolutions of a shaft per minute. In principle, it is a small centrifugal machine, somewhat like the flyball engine governor. The handle *a* is held in the hand, and the pointer *b* is pressed into the center mark of the shaft. The pointer is removable and can be placed on the spindles *c* or *d*, as shown by the dotted lines, depending on the speed of the shaft. The spindle *c* is to be used for speeds less than 500 revolutions per minute; *b*, for speeds between 500 and 1,000 revolutions per minute; and *d*, for speeds between 1,000 and 2,000 revolutions per minute. The pointer *e* is moved around the dial *f* by the movement of the weights, according to the speed at which they are driven. The instruments are usually made with three scales, and it is necessary to use the scale whose readings correspond to the spindle used. The axis of the instrument must be kept parallel with the shaft, and the spindle used must be in exact line with the axis of the shaft, or the vibration of the pointer will prevent accurate observation.

DETERMINATION OF TEST RESULTS

METHOD OF MAKING THE TEST

25. The number of assistants required when making a gas-engine test depends entirely on the number and frequency of the readings to be taken. One man should watch the brake and keep the load constant by means of the nut *e*, Fig. 1; another should take indicator diagrams and note the speed; while a third should weigh or measure the water, note the temperatures, and read the meter. This last may sometimes be divided between two observers, making four in all. In special cases, one man could take indicator diagrams and all readings; but such an arrangement is not a good one, because all the readings should, if possible, be taken at the same instant. With two observers, readings should be taken every 10 minutes. With three or four observers, readings may be taken every 5 minutes.

LOG OF TEST

________________*Gas Engine* *Made by*________________

________________*At*________________*19*____

Number	Time	Revolutions per Minute	Explosions per Minute	Temperature of Room Degrees Fahrenheit	Temperature of Exhaust Degrees Fahrenheit	Jacket Water			Dynamometer			Gas		Mean Effective Pressure	Indicated Horsepower	Brake Horsepower
						Temperature of Injection Degrees Fahrenheit	Temperature of Discharge Degrees Fahrenheit	Weight Pounds	Scale Reading Pounds	Net Pressure Pounds	Foot-Pounds per Revolution	Cubic Feet	Pressure Inches of Water			
1																
2																
3																
4																
5																
6																
7																

It is best to make several separate runs, each with a different load on the brake. Twelve or more readings should be taken with each load, so that, if readings are taken every 5 minutes, the run will last 1 hour, while with a 10-minute interval, it will last 2 hours. At least three runs should be made: one at full load, another at half load, and a third at no load. If the engine is a large one, several runs should be made at other loads, in order that the economy of the engine under these various conditions may be ascertained. It is also advisable to know the maximum load the engine is capable of carrying. The sensitiveness of the governor should be determined, where possible, by noting any change of speed when passing suddenly from full load to no load. The person in charge should be provided with a whistle. Thirty seconds before the time for taking the readings, he should blow two blasts on the whistle, when every observer should at once go to his post. At the moment for taking the readings, one blast should be blown, and all readings must, as far as possible, commence at the signal. No looker-on should be allowed to interfere with the observers, and no observer should rely on any one else, particularly an outsider, to take or record the observations allotted to him.

Before beginning a trial of any kind, the one in charge should see that a sheet is already prepared for recording the data observed while the trial is in progress. This sheet—called the *log*—should be ruled in horizontal lines and vertical columns, and each column should be headed with an explanatory phrase or note, showing what particular record is to be placed in that column. Keeping notes on loose sheets of paper is bad practice. The accompanying log of test is a very convenient form for the purpose. There should be lines enough for recording at least fifteen sets of observations. Only such observations as are taken during the test, together with the individual results from each reading, should be entered on the log.

REPORT OF THE TEST

26. After the first test is made and the data are obtained, the report should be written. A convenient form for the report is shown on the next page.

The space before the words *gas engine* should be filled in with the maker's name, and *made by* should be followed by the name of the person or engineering firm that made the test and is responsible for the accuracy of the results. The next line should contain the name of the locality where the test was made, followed by the date.

The report should be made out in duplicate, one copy being kept by the party that makes the test, and the other being given to the party for whom the test is made.

27. Clearance.—The first three dimensions in the preceding report blank are obtained by actual measurement, and need no explanation. The **piston displacement** is the product of the area and the stroke of the piston, and is usually expressed in cubic feet. The **clearance** is measured most readily in the following manner: Place the crank on the inner dead center, and close every opening but one, which should be on top. Then weigh a bucketful of cold water, and pour it through a funnel into the compression space, taking care that none is spilled and that the compression space is just full and no more. Weigh the water that remains in the bucket, and subtract this amount from the first weight. Divide the remainder by 62.5, and the result will be the clearance, in cubic feet.

Let C = clearance, in cubic feet;
W = first weight, in pounds;
w = second weight, in pounds.

Then,
$$C = \frac{W - w}{62.5}$$

In the larger engines, more than one bucket of water may be required, and W should then be taken as the sum of the weights of the full buckets, and w the sum of the weights of the buckets from which the water has been poured.

REPORT OF TEST

____*Gas Engine*

____

____*19*___

sions of Engine	
piston . . . . . In.	
on . . . . . Sq. in.	
troke . . . . . . Ft.	
acement . . Cu. ft.	
. . . . Cu. ft.	
. . . . . . Per cent.	
Data	
al . . . . Hr.	
r . . . . . . Cu. ft.	
r . . . . . . Cu. ft.	
o air	
r per hour . . . Lb.	
r temperature, inlet	
r temperature, outlet	
r temperature, ... Degrees, F.	
per minute. Average	
per hour	
per minute. Average	
per hour	
e exhaust, ... Degrees, F.	
e room . Degrees, F.	
ever arm . . . . Ft.	
average . . . . Lb.	
t of cubic foot . Lb.	

Air—weight of cubic foot . Lb.	
Mixture—weight of cubic foot . . . . Lb.	
Specific heat, gas	
Specific heat, air	
Specific heat, mixture	
Heat value cu. ft. gas . B. T. U.	
Results	
Work—ft.-lb. per min . Average	
Work—ft.-lb. per hour Average	
B. H. P. . . . . Average	
Indicated M. E. P. . . Average	
Indicated H. P. . . . Average	
Gas per I. H. P. . . . . . Cu. ft.	
Gas per B. H. P. . . . . . Cu. ft.	
Mech. eff. B. H. P. ÷ I. H. P.	
Friction loss I. H. P. − B. H. P.	
Heat Per Hour	
Supplied by gas . . . B. T. U.	
Absorbed by jacket water . . . . B. T. U.	
Exhausted . . . . . . B. T. U.	
Absorbed in work . . B. T. U.	
Radiation . . . . . . B. T. U.	
Thermal efficiency . . Per cent.	
B. T. U. per I. H. P.	

The *percentage of clearance* is found by dividing the clearance by the piston displacement.

EXAMPLE.—The diameter of an engine cylinder is 10 inches, and the length of the stroke is 12 inches. A bucket of water is found to weigh 21 pounds, and after filling the compression space the bucket and remaining water weigh 9.5 pounds. What is: (*a*) the piston displacement, in cubic feet? (*b*) the clearance, in cubic feet? (*c*) the percentage of clearance?

SOLUTION.—(*a*) The piston displacement is

$$\text{area} \times \text{stroke} = .7854 \times 10^2 \times 12 = 942.48 \text{ cu. in.}$$
$$= 942.48 \div 1{,}728 = .5454+ \text{ cu. ft. Ans.}$$

(*b*) Substituting in the formula,

$$C = \frac{W - w}{62.5} = \frac{21 - 9.5}{62.5} = .184 \text{ cu. ft. Ans.}$$

(*c*) Dividing the clearance by the piston displacement, the percentage of clearance is

$$.184 \div .5454 = .337 \text{ or } 33.7 \text{ per cent. Ans.}$$

28. Volume of Air Used.—The air used per hour may be found, roughly, by deducting the amount of gas used *per explosion* from the piston displacement, and multiplying this quantity by the number of explosions per hour.

Let P = piston displacement, in cubic feet;
G = cubic feet of gas per explosion;
E = number of explosions per hour;
A = cubic feet of air used per hour.

Then, $$A = (P - G) E$$

EXAMPLE.—A gas engine has a piston displacement of .5 cubic foot, and the amount of gas used per explosion is .05 cubic foot; when exploding 5,000 times per hour, how many cubic feet of air is used per hour?

SOLUTION.—Substituting in the formula,

$$A = (P - G) E = (.5 - .05)\, 5{,}000 = .45 \times 5{,}000 = 2{,}250 \text{ cu. ft. Ans.}$$

While this method for finding the volume of air taken into the engine is frequently used, it is better to measure the air by means of a meter. The ratio of the gas to the air is the ratio of the quantity of gas supplied per hour to the quantity of air used in the same time. Thus, if 50 cubic feet of gas is used per hour, and 400 cubic feet of air is used in the same time, the ratio of gas to air will be 50 : 400, or 1 : 8.

'. **Measurement of Gas Pressure.**—Since the pres- dealt with in gas supply and distribution are quite ., it is the custom to use a unit of measurement of the ure smaller than the pound per square inch. The rsally adopted unit is the pressure per square inch ed at its base by a column of water 1 inch high, ı is .03617 pound. For the sake of brevity and enience, the pressure is not reduced to pounds, but pressed by simply stating the height of the water n, in inches, that the pressure will balance. Thus, if is a pressure in a gas main sufficient to ce a column of water $4\frac{1}{2}$ inches high, the ure is said to equal, or to be, $4\frac{1}{2}$ inches of :.

FIG. 13

e pressure of gas is measured by means e same instruments used for air and other ›us fluids. The construction of the instru- s, however, is varied somewhat for con- nce in handling.

e most common form of gas-pressure gauge ›wn in Fig. 13, and is variously known as a **r gauge, a siphon gauge, or a U gauge.** ube *a* is made of metal, and is provided with ket *d* that will screw on any ordinary gas e in the place of a burner. The tubes *b* are made of glass, and are filled with water the zero of the scale. The scale is grad- in inches and convenient fractions of an The tube *c* is open to the air at the top. When the ure is admitted to the tube *a*, the water will sink in the *b* and will rise in *c*. The difference in the height of ater in the two tubes, measured in inches, is the meas- f the pressure exerted in *inches of water*. The depres- below zero in *b* should be added to the rise above zero The fall in one tube will not exactly equal the rise in ther, unless the tubes are of exactly equal bore. The ure of the gas is recorded in the log of the test in s of water.

30. Gas Consumption.—Comparisons with other engines should always be made as nearly as possible under the same conditions. A gas engine will lose more heat by radiation in a cold room than in a hot one, and a considerable difference in gas consumption will be noted when working with cold or with hot jacket water.

For the comparison of engines working with different kinds of gas, the heat value of the gas used, in British thermal units, is a much better basis than the gas consumption; for a gas engine that will need 20 cubic feet of city gas to develop 1 horsepower may require 80 cubic feet of producer gas per horsepower; or the same engine may develop 1 horsepower on 10 or 12 cubic feet of natural gas. If, however, the gas for the several engines to be tested should be taken from the same source, a comparison of the gas consumption per horsepower will be sufficient.

31. Temperatures.—A double purpose is served by taking the temperature of the water as it enters and as it leaves the jacket. The first is that the operator is enabled to regulate the temperature during the trial; and the second, that the water acts as a factor in the measurement of the loss of heat through the jacket. This loss of heat is, of course, not altogether the fault of the engine itself, for much depends on the way the flow of water is controlled. The best makers advise the use of a circulating tank, in which the water soon reaches the boiling point, and which reduces to a minimum the amount of heat carried away.

The determination of the exhaust temperature is not so important in a partial test as the determination of the jacket-water temperature, but it serves as a check on the indicator diagram.

The temperature of the room should be subtracted from the exhaust temperature in calculating the loss through the exhaust; for the temperature of the gas and air entering the engine cylinder is approximately the same as that of the room, and the heat thus carried into the engine must be deducted from the heat in the exhaust, in order to determine the

amount of heat due to combustion that is lost in the exhaust.

The temperature of the room will give some idea as to the loss due to radiation from the engine. An exceedingly high temperature indicates a large amount of radiation; while a normal temperature indicates but slight radiation loss. The specific heats of the gas, the air, and the mixture will be treated under Heat Losses, while the thermal and mechanical efficiencies will be taken up in connection with the subject of efficiency.

32. The readings having all been obtained, it is possible to trace the heat wastes from calculated results and to discover the cause of any abnormal loss. Nothing but a proper interpretation of the indicator diagram will show faults in valves or igniters. The wastes having been determined in a general way, the next step to consider is the calculation of the results from the data obtained. It is best to have a competent assistant to work up the results independently, the separate computations acting as a check on each other. If the two results thus obtained agree, they may generally be considered correct.

HORSEPOWER CALCULATIONS

33. To determine the brake, or delivered, horsepower, three things must be known: (1) the pressure exerted at the end of the brake arm; (2) the length of the arm; and (3) the number of revolutions made by the crank-shaft in 1 minute. The work is done on the brake at the rim of the wheel to which the brake is attached. It is not convenient to weigh the resistance of the work at the rim of the wheel; hence, this is done at the end of the brake arm—a distance l from the center of the shaft. The product of the resistance at the rim of the wheel and the radius of the wheel equals l times the pressure weighed. The result is that the work may be considered as being absorbed at a distance l from the center of the shaft—that is, at the end of the brake arm.

If the brake arm were permitted to move with the pulley against a pressure equal to that exerted on the scales, it would be exerting that thrust through a distance, per minute, equal to the distance the end of the arm would traverse in that time. Now, it is evident that in one revolution the arm will describe a complete circumference, the length of which will be equal to $2\pi l$, where l is the length of the lever arm in feet; and the total distance traversed in 1 minute will be equal to $2\pi l n$, where n is the number of revolutions made by the crank-shaft in 1 minute. This total distance traversed multiplied by the pressure p gives the number of foot-pounds of work done in 1 minute; and, since the capacity to do 33,000 foot-pounds of work per minute is 1 horsepower, the formula for the brake horsepower is

$$\text{B. H. P.} = \frac{2\pi p l n}{33{,}000} \qquad (1)$$

EXAMPLE.—What is the brake horsepower of a gas engine when the brake arm is 3 feet long, the pressure on the scales 25 pounds, and the revolutions per minute 200?

SOLUTION.—Here, $p = 25$ pounds, $l = 3$, and $n = 200$; hence,

$$\text{B. H. P.} = \frac{2 \times 3.1416 \times 25 \times 3 \times 200}{33{,}000} = 2.856 \text{ H. P.} \quad \text{Ans.}$$

Since, during any trial in which the same brake is used throughout, the brake arm does not change, the factor $\frac{2\pi l}{33{,}000}$ is the same for all readings. Ascertain this once for all, and call it c. Then simply multiply c by pn fo each separate determination. Suppose, for example, th $l = 6$ feet; then,

$$c = \frac{2\pi l}{33{,}000} = .001142 \qquad (2)$$

and $$\text{B. H. P.} = c p n = .001142\, p n \qquad (3)$$

It is generally advisable to keep the pressure p cons during a single run, in which case a new constant ca computed for each particular run, which will inclu Calling this new constant C, then

$$C = \frac{2\pi p l}{33{,}000}, \text{ or } C = cp \qquad (4)$$

In the ordinary form of Prony brake, the length of the brake arm l is the distance from the center of the crank-shaft to the point where the knife edge exerts its pressure on the scale. This distance is denoted by L in Fig. 1.

The lever arm of the strap or rope brake, illustrated in Fig. 2, is the distance from the center of the shaft to the center of the strap or rope. For example, if the diameter of the pulley is 36 inches and the belt is $\frac{1}{2}$ inch thick, the brake arm will be $\frac{36 + \frac{1}{2}}{2} = 18\frac{1}{4}$ inches.

For Prony brakes, it is necessary to take into account the weight of the unbalanced arm, because in high-speed tests a very small weight may represent a large horsepower. In order to do this, the brake is loosened from the flywheel or pulley, and the arm is allowed to rest on the platform scale as when making the test. The pressure that the unbalanced portion of the arm exerts is then weighed, and this weight must be subtracted from the pressure on the scale when making a brake test.

34. The Planimeter.—To compute the indicated horse-power from the indicator diagram, the average, or mean, height of the diagram must be found. The easiest and most accurate way to do this is to get the area of the diagram by means of a **planimeter**, and to divide this area by the

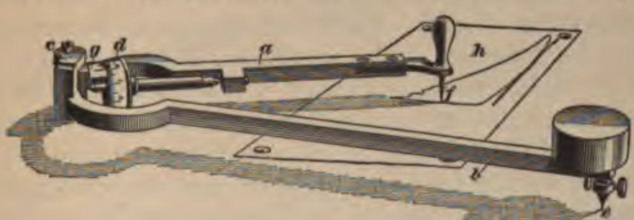


FIG. 14

length of the diagram. A planimeter suitable for this purpose is shown in Fig. 14. It consists of two bars a, b with a hinged joint c and a roller d. At the end of the bar b is a weighted point e, which is pressed into the paper just enough to fix it in one position; the bar b then moves about the

point *e* when the planimeter is in use. The point *f* on th arm *a* is the tracing point, which is moved over the outline of the diagram. The roller *d* has on one edge a flange which should roll on a smooth surface; and behind the flang are graduations, giving readings in square inches and tenth of a square inch. By means of a vernier *g*, the graduation on the roller may be read to hundredths of a square inch. There are a number of types of planimeters in use, differing in construction but operating in the same manner. Th mode of reading may differ considerably, but complet instructions are always furnished with each instrument.

The planimeter should be used on a smooth level surfac a drawing board covered with a heavy well-sized paper o with bristol board answers very well. The indicator card is fastened to the board, and the planimeter is set in about the position shown in the figure. The starting point is marked with the tracing point *f*, and the recording roller adjusted to zero. The outline of the diagram is then carefully traced with the point *f*, being sure to stop exactly on the starting point. The reading taken will be the area of the diagram, in square inches.

35. The area is read from the recording wheel and vernier as follows: The circumference of the wheel is divided into ten equal spaces by long lines that are consecutively numbered from 0 to 9. Each of these spaces represents an area of 1 square inch, and is subdivided into ten equal spaces, each of which represents an area of .1 square inch. Starting with the zero line of the wheel opposite the zero line of the vernier, and moving the tracing point once around the diagram, the zero of the vernier will be opposite some point or the wheel; if it happens to be directly opposite one of th division lines on the wheel, that line gives the exact area tenths of a square inch. The zero of the vernier, howev will probably be between two of the division lines on wheel, in which case write down the inches and tenths are to the left of the vernier zero, and from the vernier the nearest hundredth of a square inch as follows: Fin

line of the vernier that is exactly opposite one of the lines on the wheel. The number of spaces on the vernier between the vernier zero and this line is the number of hundredths of a square inch to be added to the inches and tenths read from the wheel. For example, in Fig. 15, the *0* of the vernier lies between the lines on the wheel representing 4.7 and 4.8 square inches, respectively, showing that the area is something more than 4.7 square inches. Looking along the vernier, it is seen that there are three spaces between the vernier zero and the line of the vernier that coincides with one of the lines on the wheel; this shows that .03 square inch is to be added to the 4.7 square inches read from the wheel, making the area 4.73 square inches, to the nearest hundredth of a square inch.

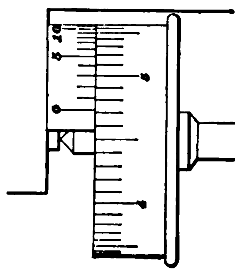


FIG. 15

36. While the form of planimeter shown in Fig. 14 is very convenient, a much simpler and less expensive instrument, called the **hatchet planimeter**, shown in Fig. 16, may be used for measuring the areas of indicator diagrams.

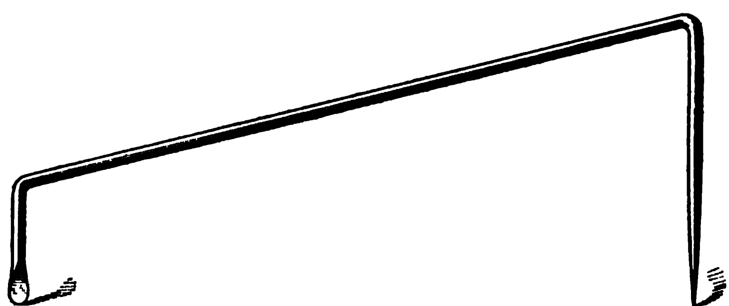


FIG. 16

This simple instrument, if accurately made and used with proper care, will give very satisfactory results. It is made of $\frac{1}{4}$-inch steel rod bent at both ends, as shown. The end *a* is sharpened for a tracing point, and the other, *b*, is flattened like a hatchet. The distance between the tracing point and

the point at which the curved hatchet end *b* touches the paper should be at least twice the length of the indicator diagram; 10 inches is a desirable length for ordinary use.

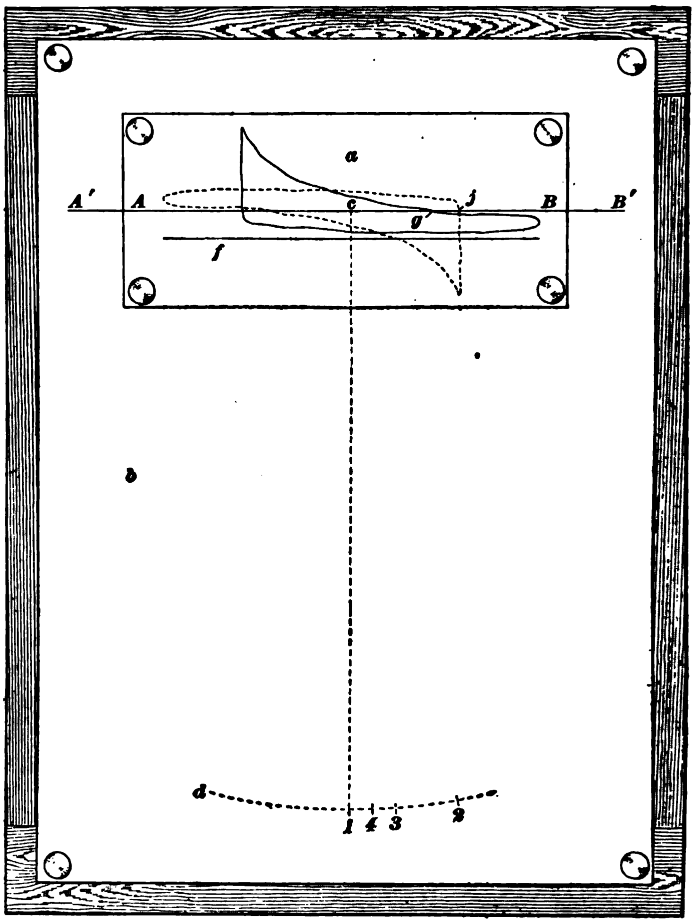


FIG. 17

The method of using the hatchet planimeter is shown in Fig. 17. The indicator card *a* is fastened to a drawing board over a piece of smooth heavy paper or bristol board *b* that is of sufficient size to furnish the surface for the records

made by the hatchet. The center of gravity *c* of the diagram must be located. This may be done approximately by inspection, or it may be found quite accurately by cutting out the diagram and balancing it on the point of a pin. Draw a line *A B* through the center of gravity parallel to the atmospheric line *f*, extending it on the bristol board beyond the card *a*. With *c* as a center and the length of the planimeter as a radius, describe an arc *d* on the paper *b*. Then place the planimeter approximately at right angles to the atmospheric line *f*, and, with the tracing point at *c*, make the mark *1* on the arc *d* with the hatchet end; proceed with the tracing point from *c* to *g*, and thence over the outline of the diagram, moving clockwise and back to *c*. During this movement, the hatchet end is free to move lengthwise on the paper *b* as the tracing point moves around the diagram. It is best to hold the instrument, just above the tracing point, between the thumb and forefinger, keeping the arm of the tracing point vertical and preventing the hatchet from slipping sidewise. The hatchet will stop at some point *2* on the arc *d*. Next revolve the card 180° about the point *c*, as shown by the dotted diagram, until the horizontal line *A B* coincides with the extensions *A′ B′* on the paper *b*.

With the hatchet at *2*, move the tracing point from *c* to *j* and around the diagram in a counter-clockwise direction, returning to *c*. The hatchet will stop at some point *3* near *1*. Locate the mid-position *4* between *1* and *3* and measure the distance from *4* to *2*, using an accurately graduated scale. A scale graduated to fiftieths or hundredths of an inch is most convenient. The area of the diagram, in square inches, will then equal the distance *4–2* multiplied by the length of the planimeter.

In order that the measurement may be accurate, it is necessary that the tracing point and the arc forming the edge of the hatchet lie in the same plane, and that the distance between the points *1* and *2* and the length of the planimeter are correctly measured. It is best to locate the actual center of gravity of the diagram, although a small error in this respect will not cause serious inaccuracy, provided the

planimeter is set approximately at right angles to the atmospheric line when starting.

The alinement of the hatchet with the point may be tested by drawing a straight line on a horizontal drawing board, and then placing both tracing point and hatchet on the line and moving the tracing point along it. If the plane of the hatchet is true, the hatchet will follow the line; if not, it will run to one side or the other.

37. Mean Effective Pressure.—To determine the mean effective pressure from the indicator diagram, the first thing to do is to find the length of the diagram. To do this, draw two lines just touching the diagram at its extreme

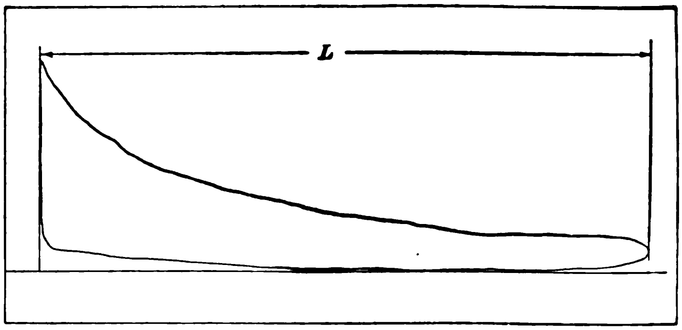


Fig. 18

limits, and perpendicular to the atmospheric line, as illustrated in Fig. 18. The length will be the horizontal distance L between these two lines. The area of the diagram divided by the length gives the mean height, or mean ordinate. This mean ordinate multiplied by the scale of the indicator spring gives the mean effective pressure, or M. E. P.

Let a = area of diagram, in square inches;
L = length of diagram, in inches;
s = scale of spring.

Then, $$\text{M. E. P.} = \frac{a\,s}{L}$$

EXAMPLE.—The area of a certain indicator diagram is 2.17 square inches, the length is 2.9 inches, and the scale of the indicator spring is 120; what is the mean effective pressure?

SOLUTION.—

$$\text{M. E. P.} = \frac{a\,s}{L} = \frac{2.17 \times 120}{2.9} = 89.8 \text{ lb. per sq. in., nearly. Ans.}$$

38. Where a planimeter is not available, the following method of finding the mean effective pressure is fairly rapid and accurate: Draw a tangent to each end of the diagram perpendicular to the atmospheric line. Then, accurately divide the horizontal distance between the tangents into ten or more equal parts (ten or twenty parts are the most convenient, but any other number may be used). Indicate, by

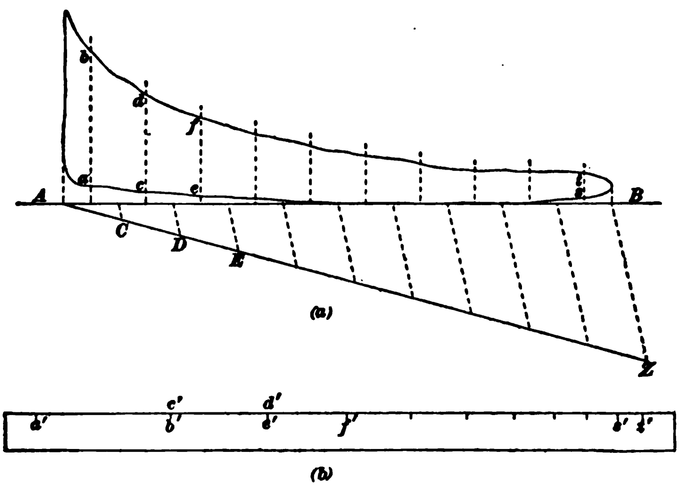


FIG. 19

a dot on the card, the center of each division, and through these dots draw lines parallel to the tangents from the upper line to the lower line of the card. On a strip of paper, mark off successively, and with care, the lengths of these lines, the total length thus representing the sum of all the lines. Measure this total length, divide by the number of measurements made, and multiply the quotient by the scale of the spring; the result will be the mean effective pressure.

A convenient method of dividing the length of the diagram AB, Fig. 19 (a), into the desired number of parts is to draw the line AZ, at a small angle to AB, and then lay off any convenient length, as AC, the required number of times

successively, along AZ. In this case, AB is to be divided into ten equal parts, hence AC is laid off ten times successively from A to Z. Next connect B to Z, and draw short lines from the points C, D, E, etc., parallel to BZ and intersecting AB. These points of intersection will divide the line AB into the same number of equal parts into which the line AZ is divided.

A more convenient method is to locate the middle points of the divisions AC, CD, DE, etc. on AZ, and draw lines from these middle points parallel to BZ intersecting AB in the middle points of its equal divisions. To find the mean effective pressure, erect perpendiculars at the middle points of these divisions as shown at ab, cd, ef, etc. Find the average length of these lines by laying them off in succession on a piece of paper, as shown at $a'b'$, $c'd'$, $e'f'$, etc. to $s't'$, Fig. 19 (b). Measure the length from a' to t', and divide it by the number of parts into which the diagram was divided. Multiply the quotient by the scale of the spring, and the result will be the mean effective pressure, in pounds per square inch.

39. The experimenter will frequently encounter an engine making a diagram similar to that shown in Fig. 20, with a loop enclosing the atmospheric line. In such a case, the area

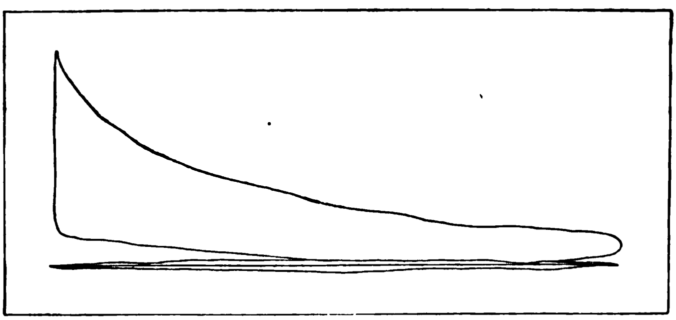


Fig. 20

of the small loop should be subtracted from that of the larger diagram, before calculating the mean ordinate. The lower line of this loop represents the pressure in the cylinder as the charge is drawn into the engine, and the upper line represents

the pressure as the exhaust gases are passing out. Hence, the area of the loop represents the work lost in these two processes.

40. Horsepower Formula.—To compute the indicated horsepower, the following formula is used:

$$\text{I. H. P.} = \frac{p\,l\,a\,n}{33{,}000}$$

in which p = mean effective pressure, in pounds per square inch;

l = length of piston stroke, in feet;

a = area of piston, in square inches;

n = number of explosions per minute.

As in the calculations for the brake horsepower, the dimensions l and a being the same for all calculations, that portion of the formula which includes these terms may be computed once for all, and $\frac{l \times a}{33{,}000}$ put equal to a constant c.

EXAMPLE.—In testing a gas engine, it is found that the mean effective pressure is 75 pounds; the stroke of the piston, 6 inches; the area of the piston, 16 square inches; and number of explosions per minute, 70. What is the indicated horsepower?

SOLUTION.— p = 75 lb. per sq. in., l = 6 in. = .5 ft., a = 16 sq. in., and n = 70. Then,

$$\text{I. H. P.} = \frac{75 \times .5 \times 16 \times 70}{33{,}000} = \frac{42000}{33000} = 1.27+ \text{ H. P. Ans.}$$

41. It is often desired to calculate, approximately, the maximum horsepower that an engine is or should be capable of developing, without going to the trouble of taking indicator diagrams. In such a case, the following formula may be used for four-cycle engines:

$$\text{I. H. P.} = \frac{d^2 p\,l\,r\,n}{1{,}000{,}000} \qquad (1)$$

in which I. H. P. = indicated horsepower;

d = diameter of piston, in inches;

p = mean effective pressure, in pounds per square inch;

r = number of revolutions per minute;

n = number of cylinders;

l = length of stroke, in inches.

This formula differs from the one given in Art. **40**, and, as it gives only approximate results, it should not be used where accuracy is required.

If the engine is of the two-cycle type, the right-hand member of formula **1** is multiplied by 2 and the formula becomes

$$I. H. P. = \frac{d^2 p l r n}{500{,}000} \qquad (2)$$

EXAMPLE.—The diameter of the cylinder of a single-cylinder four-cycle engine is 6 inches, and the length of the stroke is 8 inches. If operated with gasoline at a mean effective pressure of 75 pounds per square inch, it makes 180 revolutions per minute; what is the probable indicated horsepower?

SOLUTION.—In this case, $d^2 = 6 \times 6 = 36$, $p = 75$, $l = 8$, $r = 180$, and $n = 1$. Hence, substituting in formula **1** gives

$$I. H. P. = \frac{36 \times 75 \times 8 \times 180 \times 1}{1{,}000{,}000} = 3.89 \text{ H. P., nearly. Ans.}$$

Table I gives the most suitable compression in absolute pressure and the mean effective pressures for engines using the ordinary gas-engine fuels.

TABLE I

COMPRESSION AND MEAN EFFECTIVE PRESSURES

Fuel	Compression, in Pounds per Square Inch Absolute	Mean Effective Pressure in Pounds per Square Inch
Kerosene	45 to 70	40 to 80
Gasoline	65 to 95	60 to 100
City gas	45 to 90	45 to 95
Natural gas . . .	115 to 135	70 to 90
Producer gas . .	90 to 150	60 to 100
Blast-furnace gas	140 to 180	50 to 80

42. The amount of gas used per indicated horsepower per hour is found by dividing the gas consumed per hour by the indicated horsepower. The gas per brake horsepower is found, in a similar manner, by dividing the hourly consumption by the brake horsepower. The loss due to friction is the difference between the indicated horsepower and the

brake horsepower. Thus, I. H. P. – B. H. P. = the friction loss, in horsepower.

The heat supplied by the gas per hour is the heat value of 1 cubic foot of the gas in British thermal units multiplied by the number of cubic feet used in 1 hour; for example, if the heat value is 650 British thermal units per cubic foot and the hourly gas consumption is 50 cubic feet, the heat supplied to the engine per hour is $650 \times 50 = 32{,}500$ British thermal units.

HEAT LOSSES

43. The following computations of heat wastes are absolutely necessary only when making a complete heat analysis of the engine. It is always best that such a test be made under the direct supervision of a competent engineer. The following outline for such an analysis is given for the purpose of explaining the process involved sufficiently to enable one to determine whether such a test is desirable in any specific case.

44. The heat absorbed by the water-jacket is equal to the weight of water passed through the jacket multiplied by the temperature range; or, in other words, it is the difference between the temperature of the water when it enters the water-jacket and that of the water when it leaves the jacket. For instance, if the temperature of the entering water is 50° and that of escaping water is 180°, the temperature range is $180° - 50° = 130°$. Then, if the weight of the water passing through the jacket in 1 hour is 100 pounds, the heat carried away is $100 \times 130 = 13{,}000$ British thermal units.

45. To determine the heat carried away by the exhaust gases, the specific heat, as well as the weight of the gas, in pounds per cubic foot, must be known. City gas at atmospheric temperature and pressure weighs, approximately, .078 pound per cubic foot. The specific heat of air is, approximately, .238 at constant pressure; that of city gas may usually, without serious error, be taken as .22. For accurate observations, the specific heat must be ascertained for the particular kind of gas used. These quantities being

known, the weight and the specific heat of the mixture, or charge, can be calculated quite readily. The formula for the heat H *per hour* carried away by exhaust is

$$H = s\,w\,q\,(t_1 - t_2)$$

in which s = specific heat of mixture;

w = weight of 1 cubic foot of mixture; in pounds;

q = quantity of mixture exhausted per hour, in cubic feet;

t_1 = temperature of exhaust ascertained by pyrometer;

t_2 = temperature of room.

The volume of the mixture passing through the exhaust is found, approximately, by multiplying the volume displaced by the piston by the number of explosions.

EXAMPLE.—The weight of a cubic foot of the exhaust gases of a certain engine is found to be .068 pound per cubic foot; the specific heat of the mixture is .23; and the number of cubic feet of gas exhausted per hour is 30. If the temperature of the room is 80° F., what is the quantity of heat carried away by the exhaust when the temperature shown by the pyrometer is 350° F.?

SOLUTION.—Substituting in the formula, $H = s\,w\,q(t_1 - t_2)$, $s = .23$, $w = .068$, $q = 30$, $t_1 = 350°$, and $t_2 = 80°$.

$$H = .23 \times .068 \times 30 \times (350 - 80) = 126.68 \text{ B. T. U. Ans.}$$

46. The heat absorbed in work is that delivered to the piston in indicated horsepower. The mechanical equivalent of a British thermal unit is 778 foot-pounds; hence, as a horsepower is the capacity to do 33,000 foot-pounds of work per minute, the formula for transforming the indicated horsepower into British thermal units per hour becomes

$$\text{B. T. U.} = \frac{\text{I. H. P.} \times 33{,}000 \times 60}{778}$$

or

$$\text{B. T. U. (per hour)} = 2{,}545 \text{ I. H. P.}$$

EXAMPLE.—What is the quantity of heat absorbed in work per hour in an engine the indicated horsepower of which is 25?

SOLUTION.—Substituting in the formula

$$\text{B. T. U.} = 2{,}545 \times 25 = 63{,}625. \text{ Ans.}$$

The balance of heat that remains after subtracting the sum of the results of the foregoing three calculations from the heat supplied by the gas is charged to radiation.

INDICATOR DIAGRAMS

47. The determination of the indicated horsepower is either the only nor the most important use of the indicator iagram; it also serves to show what is taking place in the ylinder during the time that the diagram is being produced. An engineer thoroughly familiar with the operation of the

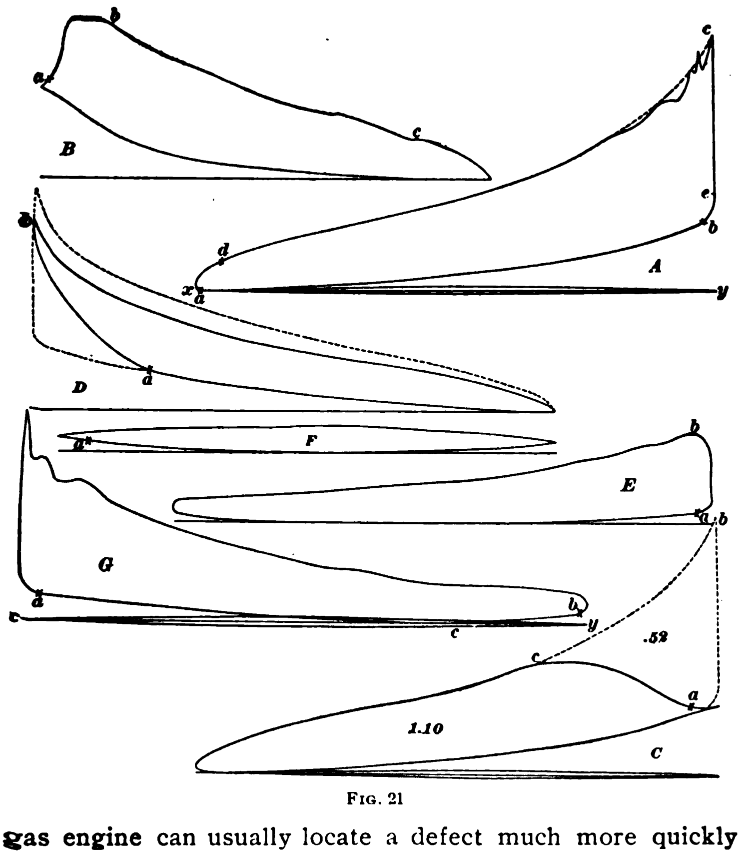


FIG. 21

gas engine can usually locate a defect much more quickly from an examination of its diagram than from a tedious examination of the engine itself.

The diagrams shown in Fig. 21 are, with one exception, copies of actual diagrams. Diagram *A* was taken from a

Hornsby-Akroyd oil engine using ordinary kerosene oil. The cycle is the same as that of the Otto gas engine, and the diagram is shown as an excellent example of what a good gas-engine diagram should be. That there is very little resistance in the admission and exhaust passages is shown by the curved lines that lie close to and just above and below the atmospheric line *x y*. These show but little rise or fall of pressure. The curve above the atmospheric line, if high, would show resistance in the exhaust passages, and that below the atmospheric line would show resistance in either the gas passages, the air passages, or both. Compression begins at *a*, and the pressure of the charge is gradually increased until, just before the piston reaches the end of the compression stroke, the charge is ignited at *b*. The point *b* of ignition is shown by the sudden change in the direction of the compression line. The advantage gained by ignition taking place just before the completion of the compression stroke is shown by the line *e c*. This line is at right angles to *x y*, proving conclusively that the charge was fully inflamed before the piston started on its forward stroke. This is as it should be; that is, the point of maximum pressure is at the beginning of the stroke, just before the piston starts forwards.

The ragged appearance of the diagram at the beginning of the forward stroke is not due to any fault of the engine, but to the vibration of the indicator spring, caused by the rapid rise of pressure from *e* to *c*. The curve would otherwise be quite regular from *c* to *d*, as shown by the dotted lines. The fall from *c* to *d* is gradual, and the form of the diagram after release at *d* shows a quick-opening exhaust valve and very little resistance in the exhaust passages.

48. An example of late ignition is shown in diagram *B*. Ignition takes place at *a* just after the crank has passed the center. The result is that the initial pressure is much below what it should be, and the maximum pressure occurs too late in the stroke. The effect of this derangement is shown more distinctly in diagram *C*, where ignition takes place

much later in the stroke. The dotted line shows the shape of the diagram obtained when ignition takes place at the proper point, the area *a b c* being the measure of the power lost. The areas are indicated by the figures on the diagram, .52 being the area, in square inches, of *a b c*, and 1.10 that of the actual diagram. This shows that very nearly one-third of the available power has been lost through faulty ignition.

49. Bad as late ignition is, too early firing is no better, because it checks the speed of the engine and causes an injurious pounding. It may even cause a reversal of the engine at low speeds and light loads. A diagram illustrating the effect of too early ignition is shown at *D*. The excessive back pressure from *a* to *b* is very evident. Too early ignition also gives the cylinder walls a chance to carry off an excessive amount of heat, owing to the slow speed of the piston at the end of the stroke. The diagram produced by such an engine lies inside that obtained when the ignition is properly timed, as shown by the dotted lines. The loss of work is shown by the difference in the areas of the two diagrams. Fortunately, this is a condition promptly made evident by the behavior of the engine, and is soon remedied.

50. Care must be taken that the diagrams produced by badly timed ignition are not confused with those produced by weakened mixtures. Examples of the latter are shown in the indicator diagrams *E* and *F*, Fig. 21. In both of these diagrams, ignition takes place at *a*, but in diagram *F* the maximum pressure is not reached until the piston is at the middle of its stroke. In *E*, the maximum pressure occurs a trifle late, but it should be noted that the line *a b* is approximately at right angles to the atmospheric line. The later occurrence of the maximum pressure is due, not to faulty timing of the ignition, but to the fact that flame propagation is slower in weak mixtures, and particularly when the compression pressure is low. The engine from which these diagrams were taken is governed by throttling both the gas and the air.

51. Diagram G, Fig. 21, indicates very clearly that the exhaust passages are obstructed. The point b should be on the atmospheric line $x\,y$, as shown in A at x. Instead, the line of the diagram does not reach $x\,y$ until the piston returns to c. This may be due to a sluggish opening of the exhaust valve or to constricted exhaust passages. Some forms of exhaust mufflers will cause the production of such a diagram.

Several of these defects may occasionally appear on one diagram. They are all more or less detrimental to the proper performance of the engine. The remedy will usually suggest itself in every case. Quite often, the remedy consists in the adjustment of the igniter mechanism or the proper setting of the valves. Sometimes, however, it will not be possible to remedy the defect except in a new design.

When desired, the expansion curve may be compared with a theoretical curve by drawing a curve according to the law $p\,v^n$ = a constant, from a point on the expansion curve where the combustion is complete. The exponent n should be so chosen that the resulting curve will represent the average practice of engines of the type under consideration. In the absence of a more accurate value, the value of n for adiabatic expansion, namely, 1.405, is sometimes used. A comparison of the theoretical with the actual curve may reveal defects in the expansion curve that could not readily be detected with the eye. It must not, however, be supposed that the theoretical and actual curves should entirely coincide.

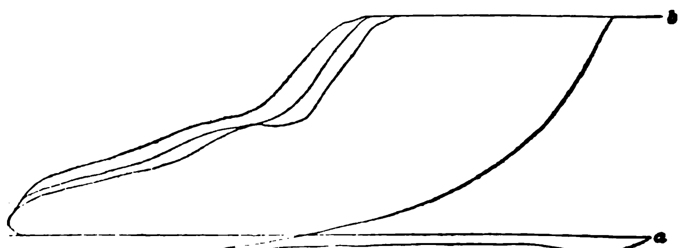


Fig. 22

52. Fig. 22 shows a diagram taken with an indicator using a spring that is too weak, and is fitted with a safety

stop, as explained in Art. 13, so that the higher pressures are not recorded. The sudden drop of the admission line at the point *a* shows that the admission valve opens too late. The horizontal line *b*, at the top of the diagram, is caused by the stop limiting the vertical travel of the pencil when it rises to this point. The diagram cannot, therefore, be used for determining the mean effective pressure.

EXAMPLES FOR PRACTICE

1. What is the mean effective pressure of an indicator diagram when the area is 1.88 square inches, the length of the diagram is 3.2 inches, and the scale of the spring is 90?

Ans. 52.9 lb. per sq. in., nearly

2. A gas engine makes 5,600 explosions per hour, the piston displacement is .75 cubic foot, and the quantity of gas used per explosion is .1 cubic foot; what is the approximate number of cubic feet of air used per hour?

Ans. 3,640 cu. ft.

3. The diameter of an engine cylinder is 15 inches, and its stroke is 21 inches. The clearance is measured by the method of Art. 27. The weight of the bucket and water before filling the clearance space is 52.5 pounds, and their weight after filling the space is 7.5 pounds. What is: (*a*) the piston displacement, in cubic feet? (*b*) the clearance, in cubic feet? (*c*) the percentage of clearance?

Ans. $\begin{cases} (a) \text{ 2.15 cu. ft., nearly} \\ (b) \text{ .72 cu. ft.} \\ (c) \text{ 33.5 per cent., nearly} \end{cases}$

4. What is the brake horsepower of a gas engine running at 225 revolutions per minute, when the pressure it exerts at the end of a 3-foot brake arm is 26 pounds?

Ans. 3.34 H. P.

5. Find the indicated horsepower of an engine from which the following results are obtained: mean effective pressure of indicator card, 96 pounds per square inch; length of stroke, 12 inches; diameter of piston, 9 inches; number of explosions per minute, 115.

Ans. 21.28 H. P.

6. How much heat is absorbed in work per hour in an engine of 23.5 indicated horsepower?

Ans. 59,807 B. T. U.

7. The exhaust gases of an engine weigh .075 pound per cubic foot, the specific heat of the mixture is .225, the number of cubic feet of gas exhausted per hour is 45, the temperature of the room is 72°, and the temperature shown by the pyrometer is 375°; what is the quantity of heat exhausted per hour?

Ans. 230 B. T. U., nearly

8. What is the approximate horsepower of a two-cylinder, four-cycle, gas engine running at 200 revolutions per minute with a mean effective pressure of 75 pounds? The diameter of the cylinder is 10 inches and the length of stroke 16 inches. Ans. 48 H. P.

SHOP TESTS

53. When the design of a gas engine has been decided on, and a number of engines built according to the design, each one is tested in the shop of the makers before shipment to the purchaser. In such cases, it is not customary to make a very exact test, as this is unnecessary for the purpose of determining whether the performance of the engine comes up to the standard. The points to be determined by the test are: (1) whether the engine runs without undue friction or overheating, and without leakage at the piston or valves; (2) whether the valves and igniter are properly timed; and (3) whether the engine uses more than the guaranteed quantity of fuel per horsepower per hour, and whether it comes up to the guaranteed maximum horsepower. In the following articles is given an outline of the procedure adopted for tests of this kind by one of the largest manufacturers of gas engines.

54. Before the engine reaches the testing stand, the piston has been fitted as accurately to the cylinder as possible, so that there is little or no possibility of the gases blowing past the piston. It is, however, almost impossible to get a new piston so that it will run quite tightly for any considerable length of time without expanding. This makes it seize the cylinder in spots causing a knocking sound, which is due to the motion of the connecting-rod on the crankpin and wristpin. Of course, this motion is very slight, and is only the necessary amount of freedom in the bearings; however, it makes quite a noise. As soon as this knocking develops, the engine is stopped, and the piston taken out of the cylinder and carefully examined. The high spots, which are now very apparent, are carefully dressed down with a smooth file. This is done very gradually, so as to

avoid taking off too much, as to a certain extent the makers depend for tightness on the piston as well as on the rings. Generally, it is necessary to remove and dress down the piston three or four times in this manner before it reaches that condition where it can be operated continuously under full load.

55. The indicator is used on every engine, but only for determining the adjustment of the valves and the timing of the ignition. When engines are being constantly tested and the number of indicators available is limited, it is found impracticable to keep the indicators in such condition that their results are trustworthy as regards the horsepower; hence, it is customary to determine the power by means of the Prony brake.

56. When the engine is to be run with illuminating gas, the fuel consumption is determined by a meter that registers to hundredths of a cubic foot. The engine is generally tested at somewhat above the rated load, though still, perhaps, below its maximum load. The gas consumed per hundred charges is measured and the number of charges* per minute counted when the engine is running under the constant test load, and proper deduction made for charges missed. Engines built to use gasoline are tested for fuel consumption by drawing the gasoline from a graduated bottle; and, since the consumption is practically constant under constant load, it is found that a comparatively short test, using up 1 or 2 gallons of gasoline, according to the size of the engine, is sufficient.

* The engine built by the company using this outline of tests is governed on the hit-and-miss principle.

EFFICIENCY

57. The **efficiency** of any engine is the ratio of the work actually performed to the work it is possible to obtain from the source from which the power is derived. The ratio of the work actually obtained from the motor to that contained in the source of supply is more often called the **total efficiency**; and, in the case of a gas engine, this may be obtained by dividing the work measured as the brake horsepower by the total work, or energy, in the gas used, for the same length of time. A convenient way to do this is to reduce the brake horsepower to equivalent British thermal units and divide the result by the British thermal units given up by the quantity of gas actually used in 1 minute. The total efficiency is seldom used in actual practice. There are, however, two other efficiencies that are frequently determined, namely, the *thermal efficiency* and the *mechanical efficiency*.

58. Thermal Efficiency.—The **thermal efficiency** is determined by dividing the heat absorbed by the engine by that supplied by the gas. The result is usually written as a percentage. In the theoretically perfect engine, the heat absorbed in work depends directly on the drop in the absolute temperature of the gas from the explosion to the exhaust temperature; and the total heat in the gas depends, in the same way, on the absolute temperature of the gas at explosion. For this reason, the formula for thermal efficiency is usually written:

$$E_t = \frac{T_1 - T_2}{T_1}$$

in which E_t = thermal efficiency;

T_1 = absolute temperature of gas at explosion;

T_2 = absolute temperature of gas at exhaust.

The thermal efficiency of any gas engine is the total efficiency of a perfect engine working between the same

initial and final temperatures, because the perfect engine utilizes all the heat given up by the gas. Hence, the thermal efficiency is sometimes called the *efficiency of the perfect engine.*

EXAMPLE.—If the initial temperature of a gas at explosion is 2,900° F. and the exhaust temperature is 1,682° F., what is the thermal efficiency of the engine?

SOLUTION.— $T_1 = 2,900° + 460° = 3,360°$; $T_2 = 1,682° + 460° = 2,142°$. Substituting in the foregoing formula, the following equation is obtained:

$$E_t = \frac{3,360 - 2,142}{3,360} = .3625, \text{ or } 36.25 \text{ per cent. Ans.}$$

59. Mechanical Efficiency.—The delivered, or brake, horsepower (B. H. P.) is the horsepower delivered by the engine as measured by the dynamometer or Prony brake.

The **mechanical efficiency** of an engine is the ratio of the brake horsepower to the indicated horsepower. It is usually expressed by the formula

$$\text{M. E.} = \frac{\text{B. H. P.}}{\text{I. H. P.}}$$

The difference between the indicated horsepower and the brake horsepower represents the power required to drive the engine, and is used to overcome the friction of the engine, so that, if the engine were running without load, the power required to run it would represent the **friction load** of the engine, or I. H. P. − B. H. P. Hence, it is easy to see that the lighter the load on an engine, the less the mechanical efficiency will be.

EXAMPLE.—(*a*) What is the friction load of an engine when the I. H. P. is 25 horsepower and the B. H. P. is 22 horsepower? (*b*) What is the mechanical efficiency?

SOLUTION.—

(*a*) Friction load = I. H. P. − B. H. P. = 25 − 22 = 3 H. P. Ans.

(*b*) $$\text{M. E.} = \frac{\text{B. H. P.}}{\text{I. H. P.}} = \frac{22}{25} = 88 \text{ per cent. Ans.}$$

Average mechanical efficiencies have been found to be about as given in Table II. An engine using a lean gas (that is, a gas of poor quality) and high compression will show

a lower mechanical efficiency than one using rich gas and moderate compression.

TABLE II

AVERAGE MECHANICAL EFFICIENCY

Size of Engine Horsepower	Four-Cycle Engine	Two-Cycle Engine
4 to 25	.74 to .80	.63 to .70
25 to 500	.79 to .81	.64 to .66
500 upwards	.81 to .86	.63 to .70

EXAMPLES FOR PRACTICE

1. The temperature of a gas at explosion, in a gas engine, is 2,740° F., and the temperature of the exhaust is 1,370° F.; what is the thermal efficiency? Ans. 42.81 per cent.

2. The indicated horsepower of a gas engine is 237, and the delivered horsepower is 215; what is its mechanical efficiency?
Ans. 90.7+ per cent.